Essays in Macroeconomics

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Dedication

To Natsuki

Abstract

This thesis is composed of three separate essays.

In the first essay of this thesis, I study the underlying mechanism behind the decision on living arrangements and household formation. The decisions to leave home and to marry are critical decisions that are at the foundation of family formation with tradeoffs between the benefits from parental altruism and the advantages of marriage. This research uses large-scale micro data on Japan to study both issues jointly. This paper proposes three possible drivers in the mechanism: (1) the strong economy of scale in Japan generated by high living cost, (2) the weak bargaining position of women on the living arrangements when they marry, and (3) the gender wage gap and the career interruption cost for women. The results suggest that high living cost discourage people to marry and live without parents and the bargaining structure encourage them to stay single and live with their own parents. The wage structure seems to have relatively weaker effects. In addition, the estimates on the preference suggest that individuals dislike living with parents-in-law and desire to leave parents' home, while marrying potential spouse is preferable.

In the second essay of this thesis, Satoshi Tanaka and I study the implication of the child support enforcement (CSE) policy. The child support enforcement policies, aimed at protecting out-of-wedlock children from financial disadvantages, brought unexpected changes in individuals' marriage and fertility behaviors during the 1980s and the 1990s. Our estimates from state-year panel data show that in states with strict CSE there has been a significant decrease in non-marital births and a significant increase in marital births. Taking into account all these changes, what are the effects of CSE on children's welfare? To answer this question, we build a heterogeneous-agent model that features endogenous marriage and child-investment decisions. Exploiting the state-level variation in enforcement, we estimate it using the National Vital Statistics Report data. We find

that men's increased willingness to marry is the driving force behind the shift from non-marital births to marital births. As evidence for the mechanism, we show that the number of marriages has risen in the states with strict CSE during the same period, consistent with the model's implication. Our model predicts that a large increase in child investment comes through a secondary effect of CSE: the shift from non-marital births to marital births increases child investment through its income effect.

In the last essay of this thesis, Bernabe Lopez-Martin and I study the long-run consequences of recessions for young individuals and the impact of government taxation. Recessions generate large increases in youth unemployment rates and young unemployed workers suffer significant losses in terms of the expected present discounted value of their labor earnings. We build a life cycle model with on-the-job human capital accumulation and aggregate and idiosyncratic productivity shocks (extended to consider ex-ante heterogeneous workers). The unemployment rate for young workers is higher and we find an important quantitative impact of the tax-wedge (consistent with cross-country empirical estimates): in countries where the tax-wedge is higher, unemployment rates are amplified, particularly for young workers. We compute the long-term earnings losses of individuals that lose their job in different states of the economy and find that losses are bigger: (1) in worse aggregate states of the economy, (2) for younger individuals, (3) in economies with a higher tax wedge, (4) for ex-ante lower ability individuals.

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Chapter 1

Living Arrangements and Household Formation in Japan

1.1 Introduction

Leaving home and marriage are critical decisions in the initial stage of family formation. When young adults leave their parents' home, they may enjoy freedom from their parents, but they also lose the benefit of parental altruism. However, when these young adults marry, they gain advantages, but they also pay the cost of commitment.

It is still unclear, however, what the key determinants are of the economic cost and benefit of leaving home and marriage in modern economies. Understanding the tradeoffs is crucial to study the mechanism of family formation and the macroeconomic implications. To do so, Japanese society has very interesting and somewhat unique characteristics. From age 25-44, around 30% of Japanese adults are single and living with their parents even after they finish their education. This allows us to jointly analyze the tradeoffs of leaving home and marrying.

This paper utilizes the large-scale micro data of the Employment Status Survey[1] in

[1] The estimates presented in this paper is computed under the sole responsibility of the author, based on the confidential anonymized data of the 2002 Employment Status Survey produced by the Statistics

Japan.

Table 1.1: Marital and Living Status of Japanese Adults

	Male		Female	
College Education	No	Some	No	Some
Single living w/o parents	3.9	3.3	2.7	6.1
Single living w/ parents	5.6	3.5	3.7	6.6
Married to non-college w/o parents	9.9	4.1	9.9	3.4
Married to some-college w/o parents	3.4	9.4	4.1	9.4
Married to non-college w/ own parents	2.8	0.9	0.6	0.2
Married to some-college w/ own parents	0.7	1.3	0.1	0.2
Married to non-college w/ in-laws	0.6	0.1	2.8	0.7
Married to some-college w/ in-laws	0.2	0.2	0.9	1.3
(Total)	27.2	22.9	25.0	24.8

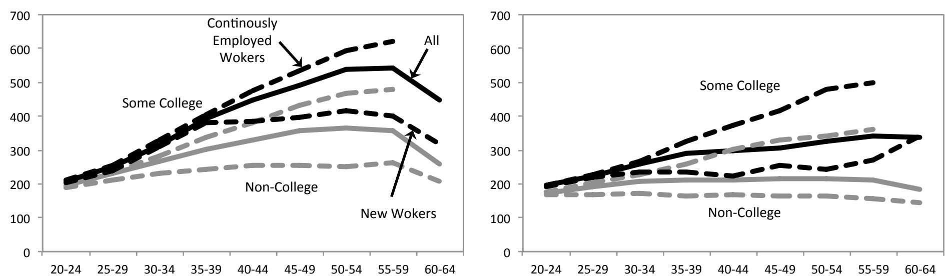


Figure 1.1: Wage Profile

Table 1.1 shows that (1) there are more educated women than educated men, (2) many people live with parents even after marriage, (3) the marriage pattern is assortative, (4) substantially more couples live with husband's parents than wife's parents, and (5) educated women are more likely to be single and live with parents.

Bureau, the Ministry of Internal Affairs and Communications, the Government of Japan and provided by the National Statistics Center in Japan under the Statistics Act (Act No. 53 of May 23, 2007) in Japan.

This paper proposes three possible drivers in the underlying of mechanism behind the decision on the marital and living status: (1) the stronger economy of scale in Japan generated by high living cost, (2) the weak bargaining position of women on the living arrangement when they marry, and (3) the gender wage gap and the career interruption cost for women we can see from the figure 1.1.

The purpose of this paper is to quantify the contribution of those determinants of the cost and benefit structure when people consider leaving home and marrying. Specifically, the benefit from parental altruism and the advantages of marriage are impossible to directly observe. Thus, this paper builds a heterogeneous agent macroeconomic model, and the key deep parameters of decisions on family formation are estimated through the method of moments.

The results suggest that high living cost discourage people to marry and live without parents and the bargaining structure encourage them to stay single and live with their own parents. The wage structure seems to have relatively weaker effects. In addition, the estimates on the preference suggest that individuals dislike to live with parents-in-law and desire to leave parents' home, while marrying potential spouse is preferable.

This paper is related to three strands of literature. First, much empirical research has been conducted on the altruistic link in families. As Altonji et al. (1997) and Hayashi (1995) found, the existence of pure altruism is generally rejected for both the United States and Japan. Namely, resource allocation within a family may depend on the income distribution within the family. However, partial altruism may still have a significant effect and this possibility is considered in this paper. Second, the methodology of this paper is based on family macroeconomics literature. In particular, the strategy to test the hypotheses is similar to Regalia et al. (2010) who study the impact of change in the wage structure on marital status. Third, many sociologists pay attention to leaving home and marriage in Japanese society. Yamada (1999) points out that there are a number of rich young adults in Japan who are single and living with their parents, and he argues that this phenomenon may widen the gap between socioeconomic classes. In addition, Raymo and Iwasawa (2005) suggest that the larger decline of marriage among educated women compared to less educated women is because of improving economic independence of women in the labor market and continued dependence on men after marriage. Thus, women may avoid or delay marriage since they are increasingly independent and want to avoid such dependence on men. This paper contributes to the literature by providing a quantitative explanation of the mechanism of family formation in Japan.

The rest of this paper is organized as follows. In section 1.2, the model is introduced. Section 1.3 describes estimations and simulations. Section 1.4 concludes.

1.2 Model

In this section, we consider a parsimonious model in which the marital and living arrangements are jointly determined. Each individual lives two periods as young and old. Let the age a be y and o, respectively. When individuals are born, their genders g, levels of education e_g, and match qualities with their own parents θ_g^p are revealed. Those attributes are drawn randomly and unchanging for their entire life. Let q_g denote (e_g, θ_g^p).

Young individual can participate in the matching mechanism with probability λ_g. In the mechanism, a single female with q_f randomly meets a single male who is a potential spouse with q_m. Then, the female draws the match qualities with the potential spouse θ_f^s and the parents-in-law θ_f^l and the male draws the match qualities θ_m^s and θ_f^l similarly. Let $(\theta_f^s, \theta_f^l, \theta_m^s, \theta_m^l)$ be Q.

Table 1.2: Matrix of Status

	Single	Married
Living Independently	SI	MI
Living with Own Parents	SP	MO
Living with Parents-in-Law	-	ML

Based on (q_f, q_m, Q), they decide to marry or not and whom they live with. Thus, their marital and living status can be one of the following five: single and living independently (SI), single and living with own parents (SP), married and living independently (MI), married and living with own parents (MO), and married and living with parents-in-law (ML), as table 2 shows. After the marital and living status is determined, people work and consume. They maintain the marital and living status when they become old, so old people can not go to the matching mechanism again and there is no divorce.

In the following, the detail of the above are presented from the period utility, the choice of marital and living status, the matching process, to the equilibrium.

1.2.1 Period Utility

After the marital and living status is determined, individuals work and consume.

Staying Single

Suppose a female does not get married. She may live independently or with her parents. If she lives independently, her period utility is

$$U_{fa}^{SI}(q_f, q_m, Q) = \frac{(w_{fae}^S)^{1-\sigma}}{1-\sigma},$$

where w is wage which depends on marital status, gender, age and education. In this case, she gets wage for single (S), female $(\underline{f})$, her age (a) and her education (e).

If she lives with her parents, her period utility is

$$U_{fa}^{SP}(q_f, q_m, Q) = \frac{\left(\frac{w_{fae}^S}{\phi^{SP}}\right)^{1-\sigma}}{1\text{-}\sigma} + \theta_f^p,$$

This appears similar to the previous one, but there are two important differences. First, the economy of scale for singles living with parents is introduced by the equivalence scale ϕ^{SP}. Second, the match quality with her parent θ_f^p is added.[2]

Single males gains similarly.[3]

Getting/Staying Married

For married couples, consumption is public between spouses. If a married female lives independently, she gains

$$U_{fa}^{MI}(q_f, q_m, Q) \quad = \quad \frac{\left(\frac{w_{fae}^S + w_{mae}^S}{\phi^{SP}}\right)^{1-\sigma}}{1\text{-}\sigma} + \theta_f^s,$$

where ϕ^{MI} is the equivalence scale for married couples living independently, and her husband gains the same except the match quality. The wife evaluates the match quality with her husband θ_f^s and the husband evaluates the match quality with his wife θ_m^s.

When a married couple live with husband's parents, the wife lives with her parents-in-law and gains

$$U_{fa}^{ML}(q_f, q_m, Q) \quad = \quad \frac{\left(\frac{w_{fae}^M + w_{mae}^M}{\phi^{MP}}\right)^{1-\sigma}}{1\text{-}\sigma} + \theta_f^s + \theta_f^l,$$

where ϕ^{MP} is the equivalence scale for married couples living with parents, and the husband lives with his own parents and gains

$$U_{ma}^{MO}(q_m, q_f, Q) \quad = \quad \frac{\left(\frac{w_{fae}^M + w_{mae}^M}{\phi^{MP}}\right)^{1-\sigma}}{1\text{-}\sigma} + \theta_m^s + \theta_m^p,$$

Those are similar to the one for the married couples living independently. The difference except ϕ is that in addition to the match quality with the spouse, she evaluates

[2]Note θ_f^p is included in q_f.

[3]Replace f by m.

the match quality with her parents-in-law and he evaluates the match quality with his own parents.

As for a married couple live with wife's parents, vice versa.

Note as consumption is public within households, the utility is non-transferable between spouses and no spouse can compensate the other when they disagree.[4]

1.2.2 Choice of Marital and Living Status

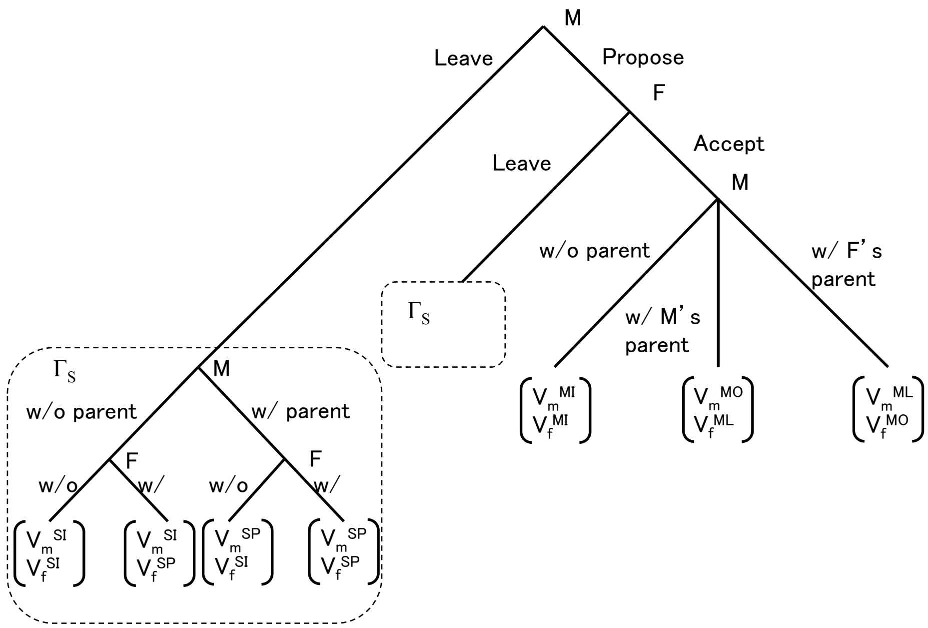
The essential problem of the model is choosing the marital and living status X from $\{SI, SP, MI, MO, ML\}$. Since they do not change their marital and living status after they decide it, when a female with q_f meets a male with q_m and the match qualities between them Q is revealed, their value functions for each marital and living status can be written as

$$V_g^X(q_f, q_m, Q) \quad = \quad U_{gy}^X(q_f, q_m, Q) + \beta U_{go}^X(q_f, q_m, Q).$$

With this payoff structure, the decision process of the choice of marital and living status is depicted as in Figure 2. The first mover is the male. He can either propose to marry the female or leave. If he leaves, he and she stay single and each of them can separately choose to live with or without their own parents. The subgame Γ_S corresponds to this separate decision. If he proposes, she can either accept it or leave. If she leaves, again he and she stay single and the subgame from this branch is identical to Γ_S. If she accepts, he chooses to live without parents, with his own parents, or with his parents-in-law. The crucial point is that the male can not commit to the living arrangement when he proposes. He may say "we will not live with my parents" at first, but that promise may not be kept if he really likes his own parents.

[4]This is crucial for the choice of marital and living status in the next subsection.

Figure 1.2: Extensive-Form Game: Lack of Commitment



1.2.3 Matching

Young females and young males meet in random matching mechanism. Let $\pi_g^O(B_{q_{g^*}}, B_Q)$ be the probability measure of an event a single participating in the mechanism meets a single with $q_{g^*} \in B_{q_{g^*}}$ and match qualities $Q \in B_Q$ are revealed, where B_X denotes a set in the Borel algebra $\mathscr{B}_X$ corresponding to the space of X. Then,

$$\pi_g^O(B_{q_{g^*}}, B_Q) \quad = \quad \sum_{e^*} \left(\frac{\alpha_{ee^*} \int \pi_{g^*}^{e^*} 1_{(e^*, \theta_{g^*}^p) \in B_{q_{g^*}}} dx_{g^* e^*}^S (\theta_{g^*}^p)}{\int \pi_{g^*}^{e^*} x_{g^* e^*}^S d(\theta_{g^*}^p)} \right) \pi(B_Q),$$

where α_{ee^*} is the probability a person with education level e meets a person with e^*, π_g^e is the share of people with education level e among gender g, $x_{ge}^S(B_{\theta_g^p})$ is the measure of single people with gender g, education e and the match quality $\theta_g^p \in B_{\theta_g^p}$, and $\pi(B_Q)$ is the probability measure of drawing $Q \in B_Q$.

1.2.4 Equilibrium

A stationary equilibrium in the economy is value function V_g, their corresponding policy functions and measures of people by marital and living status $\{x_{ge}^{SI}, x_{ge}^{SP} x_{ge}^{MI}, x_{ge}^{MO}, x_{ge}^{ML}\}$ such that

(i) the value and policy functions solve the individuals' problem,

(ii) the marriage outcome is feasible for all combinations of couples:

$$
\begin{aligned}
x_{fe_f}^{MI}(B_{\theta_f^p}, (e_m, B_{\theta_m^p}), B_Q) &= x_{me_m}^{MI}(B_{\theta_m^p}, (e_f, B_{\theta_f^p}), B_Q), \\
x_{fe_f}^{MO}(B_{\theta_f^p}, (e_m, B_{\theta_m^p}), B_Q) &= x_{me_m}^{MO}(B_{\theta_m^p}, (e_f, B_{\theta_f^p}), B_Q), \\
x_{fe_f}^{ML}(B_{\theta_f^p}, (e_m, B_{\theta_m^p}), B_Q) &= x_{me_m}^{ML}(B_{\theta_m^p}, (e_f, B_{\theta_f^p}), B_Q).
\end{aligned}
$$

1.3 Estimation and Simulation

The parameters to be determined are on the wages, and the distribution of (q_f, q_m, Q), and the utility.

1.3.1 Parameters Determined outside the Model

Wages

The wages w_{gae}^{S} and w_{gae}^{M} are set as in table 1.3. This reflects the college premium, the gender wage gap and the cost of career interruption.

Table 1.3: Wage Structure

		Female		Male	
College Education		No	Some	No	Some
Single	Young	.793	.942	1.000	1.129
	Old	.849	1.117	1.261	1.670
Married	Young	.793	.942	1.000	1.129
	Old	.793	.942	1.261	1.670

Distribution

Table 1.4 shows the shares of people with education level e, i.e. π_g^e. The distribution of θ_g^p, θ_g^s and θ_g^l are assumed to be common for both female and male and independent normal distributions. The means and standard deviations for those three distributions (μ^p, σ^p), (μ^s, σ^s) and (μ^l, σ^l) are estimated with the model. Also, we set $\alpha_{ii}/\alpha_{ij} = \alpha$ so that people with the same education level are α times more likely to meet. This α is estimated with the model.

Table 1.4: Education

	Female		Male	
College Education	No	Some	No	Some
	.502	.498	.544	.456

Utility

The scale parameters ϕ^{SP}, ϕ^{MI} and ϕ^{MP} are based on Asano and Wang (2008) who estimate the equivalence elasticity between 0.3 and 0.5. The first adult in a household is counted as 1 and the other adult is counted as 0.4. Setting $\phi^{MI} = 1.4$ is a direct application of this way of counting. As for the other two, since the adults living with parents are additional members to the households, let $\phi^{SP} = .4$ and $\phi^{MP} = 1.8$. In addition, β and σ are set to .9 and 2 respectively.

1.3.2 Estimation with Model

To estimate the remaining parameters $\Theta = (\mu^p, \sigma^p, \mu^s, \sigma^s, \mu^l, \sigma^l, \alpha)'$, this paper relies on the Method of Moments. Let M be the moments computed from the data and $m(\Theta)$ be the moments generated by the model given parameters Θ. The 7×1 vector Θ are estimated as

$$\hat{\Theta} = \arg\min_{\tilde{\Theta}} (M - m(\tilde{\Theta}))' W (M - m(\tilde{\Theta})),$$

where W is a symmetric positive definite weighting matrix. We set $W = diag(M)^{-2}$.

Target Moments

As seven parameters are estimated, at least seven target moments are necessary. The moments in table 1.1 is targeted and ther are 14 independent moments considering the feasibility of match. Thus the estimation is substantially overidentified.

The Baseline

The model's performance for hitting the targets are seen in table 1.5. The simulated moments generally match with the data moments even though the model is quite parsimonious.

Table 1.6 shows the estimated parameters. The match quality with parents-in-law tends to be quite negative. The match quality with own parents also tends to be negative but not as distinct as the first one. The match quality with potential spouse has positive mean. Thus, all other things being equal, those estimates suggest that individuals dislike to live with parents-in-law and desire to leave parents' home, while marrying potential spouse is preferable.

Table 1.5: Baseline: Data vs Model for Targets

	Data				Model			
	Male		Female		Male		Female	
College education	No	Some	No	Some	No	Some	No	Some
SI	3.9	3.3	2.7	6.1	3.8	3.0	4.5	4.7
SP	5.6	3.5	3.7	6.6	4.7	4.9	3.3	3.6
MI w. non-college	9.9	4.1	9.9	3.4	9.9	3.2	9.9	4.5
MI w. college	3.4	9.4	4.1	9.4	4.5	9.6	3.2	9.6
MO w. non-college	2.8	0.9	0.6	0.2	2.6	0.8	0.5	0.2
MO w. college	0.7	1.3	0.1	0.2	1.1	0.9	0.1	0.3
ML w. non-college	0.6	0.1	2.8	0.7	0.5	0.1	2.6	1.1
ML w. college	0.2	0.2	0.9	1.3	0.2	0.3	0.8	0.9
(Total)	27.2	22.9	25.0	24.8	27.2	22.9	25.0	24.8

Table 1.6: Baseline: Estimated Parameters

	in-law	own parents	spouse
mean	-5.608	-2.249	1.414
stdev	3.897	2.556	0.885
assortative	1.425		

1.3.3 Simulation

In this subsection, maintaining the estimated parameters unchanged, the model is solved and simulated under a few different settings. This helps to understand the mechanism driving the disparity between male and female as seen in table 1.1.

OECD Equivalence Scale

First, the equivalence scale is set to the OECD scale rather than Japanese. The results are presented in table 1.7 and we can see that people move into MI since now living parentlessly is inexpensive and they tend to desire to leave parents house.

Table 1.7: OECD Equivalence Scale

	Baseline				Model			
	Male		Female		Male		Female	
College education	No	Some	No	Some	No	Some	No	Some
SI	3.8	3.0	4.5	4.7	4.1	3.8	5.4	4.2
SP	4.7	4.9	3.3	3.6	5.2	2.5	2.8	3.0
MI w. non-college	9.9	3.2	9.9	4.5	11.1	3.9	11.1	4.9
MI w. college	4.5	9.6	3.2	9.6	4.9	11.3	3.9	11.3
MO w. non-college	2.6	0.8	0.5	0.2	1.0	0.3	0.4	0.1
MO w. college	1.1	0.9	0.1	0.3	0.4	0.8	0.1	0.2
ML w. non-college	0.5	0.1	2.6	1.1	0.4	0.1	1.0	0.4
ML w. college	0.2	0.3	0.8	0.9	0.1	0.2	0.3	0.8
(Total)	27.2	22.9	25.0	24.8	27.2	22.9	25.0	24.8

Commitment

Next, males are assumed to be able to commit on the living arrangement when they propose. Then the extensive-form game can be depicted as in Figure 1.3. Table 1.8 suggests that people would rather marry than just stay single and live with their own parents.

Table 1.8: Commitment

	Data				Model			
	Male		Female		Male		Female	
College education	No	Some	No	Some	No	Some	No	Some
SI	3.8	3.0	4.5	4.7	6.1	5.0	3.9	4.4
SP	4.7	4.9	3.3	3.6	0.1	2.1	2.4	2.8
MI w. non-college	9.9	3.2	9.9	4.5	11.1	3.0	11.1	4.6
MI w. college	4.5	9.6	3.2	9.6	4.6	9.8	3.0	9.8
MO w. non-college	2.6	0.8	0.5	0.2	3.2	0.8	0.4	0.1
MO w. college	1.1	0.9	0.1	0.3	1.1	1.8	0.1	0.3
ML w. non-college	0.5	0.1	2.6	1.1	0.4	0.1	3.2	1.1
ML w. college	0.2	0.3	0.8	0.9	0.1	0.3	0.8	1.8
(Total)	27.2	22.9	25.0	24.8	27.2	22.9	25.0	24.8

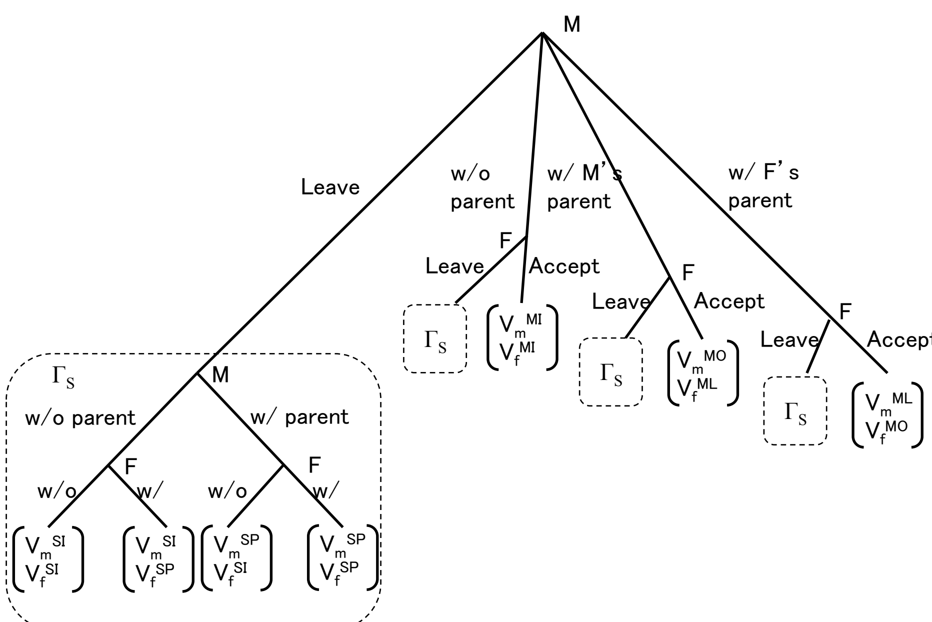


Figure 1.3: Extensive-Form Game: Commitment

Gender Wage Gap

However, table 1.9 and 1.10 suggest the effect of gender wage gap is relatively weak compared to the above two drivers.

Table 1.9: Gender Wage Gap but No Career Interruption Cost

	Baseline				Model			
	Male		Female		Male		Female	
College education	No	Some	No	Some	No	Some	No	Some
SI	3.8	3.0	4.5	4.7	3.7	2.9	4.5	4.6
SP	4.7	4.9	3.3	3.6	4.7	4.9	3.3	3.6
MI w. non-college	9.9	3.2	9.9	4.5	10.0	3.2	10.0	4.5
MI w. college	4.5	9.6	3.2	9.6	4.5	9.6	3.2	9.6
MO w. non-college	2.6	0.8	0.5	0.2	2.6	0.8	0.5	0.2
MO w. college	1.1	0.9	0.1	0.3	1.1	0.9	0.1	0.4
ML w. non-college	0.5	0.1	2.6	1.1	0.5	0.1	2.6	1.1
ML w. college	0.2	0.3	0.8	0.9	0.2	0.4	0.8	0.9
(Total)	27.2	22.9	25.0	24.8	27.2	22.9	25.0	24.8

Table 1.10: Career Interruption Cost but No Other Gender Wage Gap

	Baseline				Model			
	Male		Female		Male		Female	
College education	No	Some	No	Some	No	Some	No	Some
SI	3.8	3.0	4.5	4.7	3.9	3.0	4.8	5.1
SP	4.7	4.9	3.3	3.6	4.6	5.4	3.3	3.3
MI w. non-college	9.9	3.2	9.9	4.5	10.0	2.9	10.0	4.5
MI w. college	4.5	9.6	3.2	9.6	4.5	8.4	2.9	8.4
MO w. non-college	2.6	0.8	0.5	0.2	2.6	0.8	0.4	0.2
MO w. college	1.1	0.9	0.1	0.3	1.1	2.0	0.1	0.3
ML w. non-college	0.5	0.1	2.6	1.1	0.4	0.1	2.6	1.1
ML w. college	0.2	0.3	0.8	0.9	0.2	0.3	0.8	2.0
(Total)	27.2	22.9	25.0	24.8	27.2	22.9	25.0	24.8

1.4 Conclusion

The results suggest that high living cost discourage people to marry and live without parents and the bargaining structure encourage them to stay single and live with their own parents. The wage structure seems to have relatively weaker effects. In addition, the estimates on the preference suggest that individuals dislike to live with parents-in-law and desire to leave parents' home, while marrying potential spouse is preferable.

Chapter 2

Men's Rush to Marriage: Implications of the Child Support Enforcement Policy for Marriage, Fertility, and Long-Term Inequality

2.1 Introduction

Since the late 1970s, the U.S. federal government has taken a number of steps to strengthen the state-regulated, private child support systems. In the mid-1970s, it created the Office of Child Support Enforcement (OCSE), required all states to establish comparable state offices, and raised federal funding for three-quarters of the states' expenditures on child support enforcement. It also passed major federal regulations in the 1980s requiring states to strengthen paternity establishment, to create legislative guidelines for states' child support orders, and to withhold obligations from fathers' wages. As a consequence, many states increased their child support collections significantly (as shown in Figure 2.1) by establishing child support enforcement (CSE) policies through the 1980s and 1990s.[1]

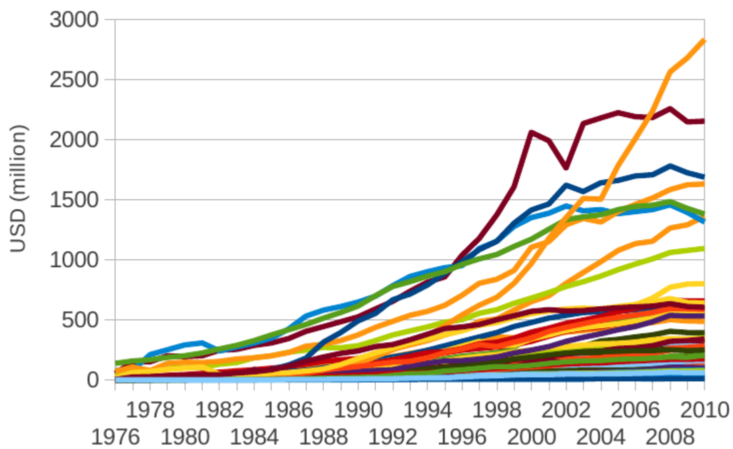


Figure 2.1: Child Support Collection Amount by States. Source: OCSE

However, these CSE policies have also brought unexpected changes in people's marriage and fertility behaviors in the United States. In addition to a reduction of non-marital births, which is well-known in the literature,[2] we find significant increases in the number of marital births and also in marriages in the states with strict CSE. (See Table 2.1 for a summary of our estimates.[3,4]) Why did these changes happen after the CSE policies were strengthened? Furthermore, what was the effect of CSE on children's welfare if we take into account all these changes?

[1] CSE policies consist of child support legislation and plans of state's expenditures for CSE cases. The major CSE laws are on genetic testing, paternity establishment, wage withholding under delinquency, immediate wage withholding for new cases, universal wage withholding, and state income tax interception. The years when these legislations were approved, vary across states. See the work of Huang (2002) for more details.

[2] See the work of Case (1998), Huang(2002), Garfinkel et al. (2003), and Aizer and McLanahan (2006), for example.

[3] In Table 1, the *marriage rate* is defined as the number of marriages per population. To create the total fertility rate (total period fertility rate), first we calculate age-specific marital and non-marital birth rates for six age groups. Then we sum them up and multiply the sum by five.

[4] According to our estimate, a 10% increase in the child support collection rate has decreased the total fertility rate for non-marital births by 9.8%, increased the total fertility rate for marital births by 1.1%, and increased the marriage rate by 3.1% (as summarized in Table 1) relative to the trends.

Table 2.1: The Effects of a 10% Increase in the Child Support Collection Rate

Variable	Level in 1980	Changes in Level	Changes in %
Total Fertility Rate			
for Non-Marital Births	0.304	$-\Delta$ 0.0297	$-\Delta$ 9.8%
for Marital Births	1.582	$+\Delta$ 0.0172	$+\Delta$ 1.1%
Marriage Rate	0.042	$+\Delta$ 0.0013	$+\Delta$ 3.1%

To address these issues, we build a heterogeneous-agent model which features marriage and child investment decisions. In our model, people form marital or non-marital relationships in a stable matching equilibrium and also choose the number and the quality of children within each relationship. As in the work of Weiss and Willis (1985), here marriage allows couples to achieve the efficient level of public good investment. If a couple chooses a non-marital relationship, however, only the mother can determine the level of child investment; the father transfers child support payments to the mother but often at inefficiently low levels because of the lack of coordination. We compute our model by extending the Gale and Shapley (1962) algorithm. And we estimate using the total fertility rate for marital and non-marital births (the National Vital Statistics Report: Natality data published by the Centers for Disease Control and Prevention), exploiting the exogenous variations in CSE across the states during the period 1980 - 1997.

We find that men's increased willingness to marry is the driving force behind the shift from non-marital births to marital births. After the strengthening of CSE policies, facing the larger cost per child due to the mandatory child support payment, men in non-marital relationships may

1. Reduce the number of children and, instead, increase investments in child quality.

2. Reduce the number of children and, instead, increase the private consumption.

3. Get married to avoid the child cost change.

We find that option (1) is not attractive to unmarried fathers, because to increase a child's quality investment they have to transfer money to the mothers. But these transfers involve two types of inefficiency: First, in non-marital relationships, since the mothers are not considering the fathers' utility, they do not invest all the money in children's quality. They use some of it for their private consumption. Second, if the mother in a non-marital relationship is on a welfare program, then the state government takes away a significant portion of child support payments made by the biological father.[5] Therefore, fathers' investments do not really increase a child's quality. And unmarried fathers are thus left with options (2) or (3). Through our estimation, we show that men split between reducing the number of children and increasing marriage when facing the increased degree of CSE. This result hinges upon finding parameters that govern the elasticity between the utility from consumption and from children.

After estimating the model's underlying parameters using marital and non-marital total fertility rates in the state-year panel data, we check the identification of the model by predicting the increase of marriages found in the data. This is crucial to distinguish our story from the other alternatives. From the reduced-form regression, a 10% increase in the child support collection rate induces a 3.1% increase in the marriage rate and a 1.93% increase of the number of ever-married people at age 45. The model predicts a rise of 1.39% in the number of ever-married people, accounting for 72% of the increase in marriages in the data.

Finally, using the estimated parameters, we find that there are secondary, positive effects of CSE on child investment. CSE was originally supposed to protect out-of-wedlock children and, thus, to improve child investment in non-marital relationships. However, we find that a large gain in the average child investment comes through a shift from non-marital births, when we allow for the income effects on child quality investment. Our model predicts that a 10% increase in the child support collection

[5] In most states, child support payments to mothers on Aid to Families with Dependent Children (AFDC) are now taxed 100%. Some states allow a $50 pass-through per month.

rate will increase average child investment by 1.1%. Assuming a general human capital transmission function, we find that stronger CSE will men's decrease 90-10% income ratio of the next generation by 2.2%. We find that the effects are especially strong for the bottom group of the income distribution.

Related Literature

Our work here is related to a sizable number of studies in the sociology and economics literature that examine the effect of CSE on non-marital births. Case (1998) and Garfinkel et al. (2003) analyze state level data similar to ours. Case (1998) finds significantly lower non-marital birth rates in the states where legislation allows genetic testing to establish paternity, permits paternity establishment up to age 18, and establishes presumptive guidelines for setting child support awards. Extending her framework, Garfinkel et al. (2003) use paternity the establishment rate[6] and child support collection amounts per cases,[7,8] and show significantly negative effects of their CSE measures on non-marital births. Huang (2002), Aizer and McLanahan (2006), and Plotnick (2007) look into microeconomic data. Huang (2002) and Aizer and McLanahan (2006) use the U.S. Labor Department's National Longitudinal Survey of Youth 1979 (NLSY79) to examine whether CSE is related to the likelihood that a women's first birth is premarital. And both studies show that CSE reduces the risk of out-of-wedlock births. So do Plotnick et al. (2007), but they use the University of Michigan's Panel Study of Income Dynamics (PSID) for their analysis.

Compared to studies of non-marital births, not much research has been done on the effect of CSE on marital births and marriages. Huang (2002) is one of the exceptions; he uses the multinomial logit model for NLSY79 and finds a significant increase in the

[6]The paternity establishment rate is defined as the number of paternity establishments for non-marital births over the total number of non-marital births.

[7]More precisely, they consider only cases with single mothers on Aid to Families with Dependent Children (AFDC).

[8]Those are calculated from the Office of Child Support Enforcement (OCSE) 1980 - 1997 Annual Reports to Congress.

likelihood of marital births in the states with strict CSE. Our work is motivated by his work, but we use state-year panel data constructed from the CDC's National Vital Statistics Report (NVSR). We show that there is an increase in marital births also in our state panel data. For marriage, the work of Acs and Nelson (2004) is the only research, as far as we know, which reports the effect of strengthened CSE on marital statistics. They show that two-parent families have increased in the states where CSE has been strengthened, especially among low-income people. They use the University of Michigan's 1997 and 1999 National Surveys of America's Families and apply the difference-in-difference estimation method to derive their results. Unlike their approach, we do not analyze the 'stock' of married people. Instead, we look at the marriage rate in the state-year panels. Our data cover the longer period, and our result is more robust than theirs.

In terms of theory, our study is related to the growing literature on family economics. One of the most relevant works is Weiss and Willis (1985). They show that non-marital childbearing potentially involves inefficiencies in child investment. This is because single mothers do not take into account fathers' utility when investing, and if fathers know that, they do not transfer much money to mothers. Del Boca and Flinn (1995) apply Weiss and Willis (1985)'s framework to explain why child support payments are low in the U.S. data. Our study is also based on the work of Weiss and Willis (1985). And we extend their model to the stable matching problem. Other relevant studies which analyze child support and/or CSE are those of Chiappori and Weiss (2006), Chiappori and Weiss (2007), and Greenwood et al. (2003). All these use two-period models, which enable them to analyze the divorce situations. Other relevant works are those which apply the two-sided matching problem to an analysis of the marriage market. Del Boca and Flinn (2005) compute a stable matching equilibrium applying Gale and Shapley (1962)'s algorithm. We further extend their framework, allowing for marital and non-marital relationships. Finally, our work is related to those which study the intergenerational transmission of human capital. These include the work of

Aiyagari et al. (2000), Greenwood et al. (2003), and Kocharkov (2010), who analyze the effects of the government's family policies on the next generation's income distribution. Also, in the growth context, De La Croix and Doepke (2003) and Moav (2005) show that economies with a less equitable income distribution have a lower rate of economic growth as the consequence of the quantity-quality trade-off of child investment.

The next section describes our economic model and defines an equilibrium. Sections 2.3 and 2.4 describe the data and the estimation methodology. Section 2.5 presents the results and the implications. Section 2.6 concludes.

2.2 The Model Economy

We develop a structural economic model in order to identify the channels through which changes in the degree of CSE have effects on marriage decisions and fertility choices. In our model, equal population of women and men enter the marriage market only once in their life, form either marital or non-marital unions in a stable matching equilibrium, and choose about a quantity and quality of children. Our model is static in the sense that people make a decision about marriage and fertility only once in their lives.

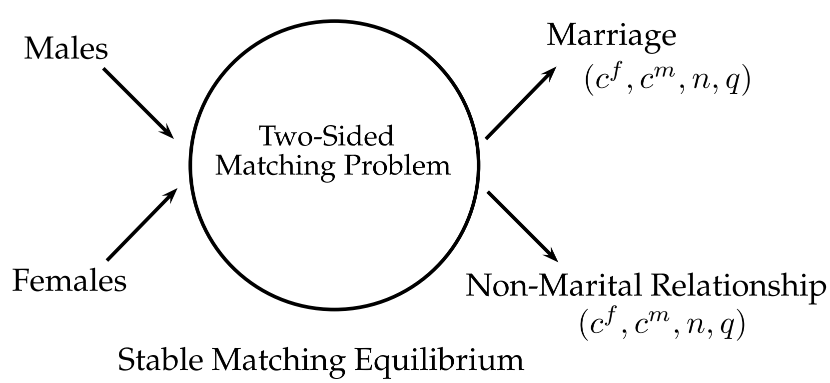


Figure 2.2: Structure of the Model Economy

2.2.1 Setup

The agents in the economy are unit masses of females (f) and males (m), who each live for one period. Among each of these types of agents, individuals differ in their human capital level, $h^f \in \mathcal{H}^f \subset \mathbf{R}_+$ and $h^m \in \mathcal{H}^m \subset \mathbf{R}_+$, and their charm level, $a^f \in \mathcal{A} \subset \mathbf{R}$ and $a^m \in \mathcal{A} \subset \mathbf{R}$. Assume that there is only a finite number of types of people in the economy and that the number of types is the same for women and men. The sets of all types of people are denoted as $\{(h_i^f, a_i^f)\}_{i \in \mathcal{I}^f}$ for women and $\{(h_j^m, a_j^m)\}_{j \in \mathcal{I}^m}$ for men, where $\mathcal{I}^f$ is the set of all indices for women's type and $\mathcal{I}^m$ is the set of all indices for men's type. We assume that $n(\mathcal{I}^f) = n(\mathcal{I}^m) = N_h \times N_a$, where $n(X)$ denotes the cardinality of a set X, N_h is the number of possible human capital levels, and N_a is the number of possible charm levels. Both N_h and N_a are common across sex. We assume that each individual possesses only one sexual identity, and thus let $\mathcal{I}^f \cap \mathcal{I}^m = \emptyset$. Finally, assume that people are equally populated across each type (h_i, a_i).

After they are born, both men and women enter the frictionless marriage market, where each person chooses one partner and forms a relationship - either marriage or a non-marital relationship. As we will discuss later, people can form a relationship with whomever they want as long as the partner agrees. But, by assumption, they cannot have more than one relationship. Once people form a relationship, they determine allocations, (c^f, c^m, n, q), where $c^f \in \mathbf{R}_+$ is women's private consumption, $c^m \in \mathbf{R}_+$ is men's private consumption, $n \in \mathbf{R}_+$ is the number of children for the couple, and $q \in \mathbf{R}_+$ is the quality of each child for the couple. We assume that n and q are local public goods within couples.

Preferences Preferences are identical across sex, and are denoted as $u(c, a') + v(nq)$. People get utility from their private consumption c and from the number of children times the quality of children nq. Also, they get utility from their partner's charm a'. For men who choose non-marital relationship, probably, fathers are not always staying with their children.[9] And, thus, we take into account the possibility of a discount of their utility from children as $u(c, a') + \delta v(nq)$ where $\delta \in [0, 1]$.

Technology Couples in either marriage or a non-marital relationship invest in the number and the quality of children. Increasing one unit of the number, it requires fixed amounts of time ϕ and consumption good ψ. Increasing the quality requires an input of per-child educational investment s. Then children's quality is determined by a function, $q = f_1(s)$ for married couples, and $q = f_0(s)$ for non-married couples.

Child Support Men in non-marital relationships make child support payments to the mothers of their children. The payments consist of a mandatory portion and a voluntary portion. Let $wh^m\gamma\tau^{cs}(n)$ be the amount of mandatory child support payments for men whose human capital level is h^m and who have n children out of wedlock, where $\tau^{cs}(n)$ is the child support order, which depends on the number of children and which determines the payment rate from their income. Assume that $\gamma \in [0, 1]$ is the strength of CSE, which state governments can control. And, w is the market price of human capital.

Aid to Families with Dependent Children (AFDC) Mothers in non-marital relationships who meet an income test are eligible for AFDC and receive monetary payments. AFDC is a welfare program provided by each state government. In the model, we assume that there are no differences across states. Mathematically, $g(e, n)$ is the amount of receipts from AFDC, which is decreasing in the mother's income e and increasing in the number of her children n.

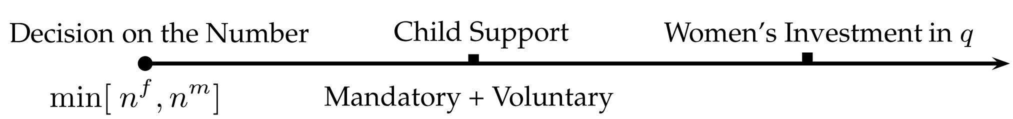


Figure 2.3: Timeline of Decisions in Non-Marital Relationships

[9] According to McLanahan et al. (2001), more than half of new unwed parents are not cohabiting in the 1998-1999 data in the U.S..

2.2.2 Couples in Non-Marital Relationships

Allocations within the couples in non-marital relationships are determined through three stages, shown in Figure 2.3. In the first stage, women and men decide on the number of children they will have together. In the second stage, men pay mandatory child support, and choose the amounts of their private consumption and voluntary child support payments. In the third stage, women choose their private consumption and child investment.

Let us first focus on the last stage and go backward. Given the number of children n, the characteristics of the couple $\Phi \equiv (h^f, a,^f h^m, a^m)$, the strength of CSE γ, and a voluntary payment of child support from the biological father T^{cs}, a woman in a non-marital relationship (that is, still single, S) solves the following problem:

$$V_S^f(n, \Phi, \gamma, T^{cs}) \equiv \max_{c^f, s \geq 0} \; u\left(c^f, a^m\right) + v\,(nq)$$

subject to

$$q = f_0(s)$$

$$c^f + (\psi + s)n = wh^f(1 - \phi n) + \max\left[\underbrace{g\left(wh^f(1 - \phi n), n\right)}_{\text{AFDC}}, \; \underbrace{wh^m \gamma \tau^{cs}(n) + T^{cs}}_{\text{Mandatory+Voluntary CS}}\right],$$

where V_S^f is the woman's utility value, c^f is her consumption, s is the amount of investment per child, q is the quality of each child, ψ is the consumption good cost per child, ϕ is the time cost per child, and $g(w^f, n)$ is the AFDC receipt. If there is a child support payment to a woman on AFDC from the biological father, it is taxed 100%. Denote the solution to the quality of the children in the above problem as $q_0^*(T^{cs}; n, \Phi, \gamma,)$.

The problem for a man in a non-marital relationship is defined in the following way. Given the number of children n, the characteristics of the couple Φ, the degree of CSE γ, and the woman's response function $q_0^*(T^{cs}; n, \Phi, \gamma)$, a man chooses his private consumption c^m and voluntary child support payments T^{cs}:

$$
\begin{aligned}
V_S^m(n,\Phi,\gamma;q_0^*) \equiv \max_{c^m, T^{cs}\geq 0} \; & u\left(c^m, a^f\right) + \delta v\left(nq_0^*(T^{cs};n,\Phi,\gamma)\right) \\
\text{subject to} & \\
c^m + T^{cs} = & wh^m\left(1-\gamma\tau^{cs}(n)\right),
\end{aligned}
$$

Let $T^{cs*}\left(n,\Phi,\gamma;q_0^*\right)$ be the solution for the child support payments in the above problem.

Finally, in the first stage, the number of children is determined as the minimum of the numbers which each partner wants:

$$
n_0^*(\Phi,\gamma) \equiv \min\left[\arg\max_n V_S^f(n,\Phi,\gamma,T^{cs*}), \arg\max_n V_S^m(n,\Phi,\gamma;q_0^*)\right].
$$

Once the number is determined, the utility values for each member of the couple in a non-marital relationship are well-defined. The set of utility values is denoted as $\left\{\hat{V}_S^f(\Phi,\gamma),\hat{V}_S^m(\Phi,\gamma)\right\}_{\Phi\in\mathcal{F}}$, where $\mathcal{F}$ is the set of all possible patterns of a couple's characteristics, which includes $N_h^2\times N_a^2$ patterns of coupling. Let $\hat{V}_s^f(\Phi,\gamma)$ be defined as $\hat{V}_S^f(\Phi,\gamma)\equiv V_S^f(n_0^*,\Phi,\gamma,T^{cs*})$ and $\hat{V}_s^m(\Phi,\gamma)$ be defined as $\hat{V}_S^m(\Phi,\gamma)\equiv V_S^m(n_0^*,\Phi,\gamma;q_0^*)$.

2.2.3 Married Couples

Unlike couples in non-marital relationships, married couples stay together with their children for a long time; thus, we assume that the allocation within marriage is determined through a Nash bargaining problem:

$$\max_{c^f,c^m,n,q,t^f,t^m \geq 0} \left[V_M^f(c^f,n,q;\Phi) - \hat{V}_S^f(\Phi,\gamma) \right]^{\frac{1}{2}} \times \left[V_M^m(c^m,n,q;\Phi) - \hat{V}_S^m(\Phi,\gamma) \right]^{\frac{1}{2}}$$

subject to

$$q = f_1(s)$$
$$\phi n = t^f + t^m$$
$$c^f + c^m + (\psi + s)n = wh^f(1-t^f) + wh^m(1-t^m)$$
$$V_M^f(c^f,n,q;\Phi) \geq \hat{V}_S^f(\Phi,\gamma)$$
$$V_M^m(c^m,n,q;\Phi) \geq \hat{V}_S^m(\Phi,\gamma)$$

and

$$V_M^f(c^f,n,q;\Phi) \equiv u\left(c^f,a^m\right) + v\left(nq\right) + \kappa$$
$$V_M^m(c^m,n,q;\Phi) \equiv u\left(c^m,a^f\right) + v\left(nq\right) + \kappa$$

where t^f and t^m are the time spent for child nurture by each member of the couple, and which must sum to ϕn. Here $\kappa \in \mathbf{R}$ is the utility gain of marriage, which is common across couples. We denote the solution of the utility values for the above problem for married (M) couples as $\left\{\hat{V}_M^f(\Phi,\gamma), \hat{V}_M^m(\Phi,\gamma)\right\}_{\Phi\in\mathcal{F}}$. It is often true that there does not exist a solution to the above problem. In that case, we simply assume that $\hat{V}_M^f(\Phi,\gamma) = \hat{V}_M^m(\Phi,\gamma) = -\infty$, so that couples choose non-marital relationships in the stable matching equilibrium.

As in the work of Weiss and Willis (1985), here marriage allows couples to attain the efficient level of public good investment through Nash bargaining. However, in non-marital relationships, mothers choose their private consumption and child investment without taking into account fathers' utility; thus, mothers under-invest in children. Furthermore, if fathers know their payments will not fully used for their children by mothers, they will not transfer enough child support payments to the mothers. Through these steps, inefficiency in public good investment arises in non-marital relationships.

2.2.4 Stable Matching Equilibrium

In this economy, women and men look for a partner in the frictionless marriage market. Again, they can form a marital or a non-marital relationship with whomever they want as long as the partner agrees, but we assume that they cannot form more than one relationship at the same time. Also, in equilibrium, all the agents must form some relationship with a partner.

Formally, we consider a set of matchings (μ_S, μ_M), where μ_S is a matching for non-marital relationships (single S) and μ_M is a matching for marital (M) relationships. Mathematically, μ_S and μ_M are mappings from $\mathcal{I}^f \cup \mathcal{I}^m$ onto itself.[10] In particular here we only consider the sets of mappings which satisfy the following properties.

Definition 1. *A pair (μ_S, μ_M) is defined as an* ***acceptable pair of matchings*** *if it satisfies the following properties:*

1. *$\forall R \in \{S, M\}$, if $\mu_R(x) \neq \emptyset$, then $\mu_R(\mu_R(x)) = x$.*
2. *$\forall R \in \{S, M\}$, if $x \in \mathcal{I}^g$ and $\mu_R(x) \neq \emptyset$, then $\mu_R(x) \in \mathcal{I}^{g'}$, where $g, g' \in \{f, m\}$ and $g \neq g'$.*
3. *$\forall R, R' \in \{S, M\}$ with $R \neq R'$, if $\mu_R(x) \neq \emptyset$, then $\mu_{R'}(x) = \emptyset$ for all $x \in \mathcal{I}^f \cup \mathcal{I}^m$.*

In short, an acceptable pair of μ_S and μ_M is a set of mappings which specify the couples in each relationship and in which no one in the pairs has more than one relationship. Next, we define an equilibrium of the economy using these matchings μ_S and μ_M.

Definition 2. *Given $\gamma \in [0, 1]$, a* ***stable matching equilibrium*** *is an acceptable pair of matchings, (μ_S, μ_M), which satisfies these two conditions:*

[10] Remember that we assumed $\mathcal{I}^f \cap \mathcal{I}^m = \emptyset$ at the beginning of this section. Thus, women and men are indexed by different numbers. And, $\mathcal{I}^f \cup \mathcal{I}^m$ denotes the entire set of types in the population.

1. $\forall R \in \{S, M\}$, *a woman* $i \in \mathcal{I}^f$ *with* $\mu_R(i) \neq \emptyset$ *receives utility,*

$$\hat{V}_R^f\left(h_i^f, a_i^f, h_{\mu_R(i)}^m, a_{\mu_R(i)}^m, \gamma\right),$$

   and a man $j \in \mathcal{I}^m$ *with* $\mu_R(j) \neq \emptyset$ *receives utility,*

$$\hat{V}_R^m\left(h_{\mu_R(j)}^f, a_{\mu_R(j)}^f, h_j^m, a_j^m, \gamma\right).$$

2. *(No Blocking) There does not exist a pair of couples* $(i, \mu_R(i))$,$(\mu_{R'}(j), j)$, *and relationships* $R, R', R'' \in \{S, M\}$ *such that*

$$\hat{V}_{R''}^f\left(h_i^f, a_i^f, h_j^m, a_j^m, \gamma\right) > \hat{V}_R^f\left(h_i^f, a_i^f, h_{\mu_R(i)}^m, a_{\mu_R(i)}^m, \gamma\right),$$
$$\hat{V}_{R''}^m\left(h_i^f, a_i^f, h_j^m, a_j^m, \gamma\right) > \hat{V}_{R'}^m\left(h_{\mu_{R'}(j)}^f, a_{\mu_{R'}(j)}^f, h_j^m, a_j^m, \gamma\right).$$

The second condition in the equilibrium definition requires that there are no pairs of a woman and a man who jointly deviate from their current relationships and obtain higher utility by starting a new relationship with the partner. In other words, the equilibrium is a *core of matching game*.

As in the last part of this section, we now pose a theorem for the existence of a stable matching equilibrium. The proof is an extension of Gale and Shapley (1962)'s.

Theorem 3. *A stable matching equilibrium exists in the economy.*

Proof. In Appendix A.1.

□

2.2.5 Computing an Equilibrium

Definition 4. *A stable matching equilibrium* (μ_S, μ_M) *is* ***M-optimal*** *if every man likes it at least as well as any other stable matching equilibria. Similarly, a stable matching* *equilibrium (ν_S, ν_M) is **W-optimal** if every woman likes it at least as well as any other stable matching equilibria.*

Based on the approach of Del Boca and Flinn (2005), we focus on two extreme stable matching equilibria, the one that is most beneficial to men (the M-optimal stable matching equilibrium) and the one most beneficial to women (the W-optimal stable matching equilibrium). A straight-forward extension of the Gale and Shapley algorithm enables us to compute at least these two equilibria. In addition, because assuming that each individual has strict preference over mates, each of these equilibria turns out to be unique.

Assumption 2.1. *All the agents have strict preference over partners' types.*

To satisfy the above assumption, differences in human capital level have to create strictly different utility values for potential partners.[11] When couples choose non-marital relationships, it is not obvious because some low-income men might not make any child support payments. Then if those men's charm levels are the same, women become indifferent among the different types of men. To exclude this situation, we assume that $\gamma > 0$ always holds. If γ is strictly positive, then women get better off by having a non-marital relationship with a man with higher income because the state government transfers child support payments proportionally to men's income. Thus, Assumption 5 is always satisfied.[12]

Theorem 5. *Under Assumption 5, both the M-optimal stable matching equilibrium and the W-optimal stable matching equilibrium are unique.*

Proof. See Appendix A.1. □

[11] For charm, the utility function specified in Section 2.4.6 automatically creates strict differences.

[12] Here, we implicitly assuming that there do not exist (h_j^m, a_j^m) and $(h_{j'}^m, a_{j'}^m)$ such that $h_j^m > h_{j'}^m$, $a_j^m < a_{j'}^m$, and $\hat{V}_R^f(h_i^f, a_i^f, h_j^m, a_j^m) = \hat{V}_R^f(h_i^f, a_i^f, h_{j'}^m, a_{j'}^m)$ for some i and R. When we actually compute an equilibrium and discretizing the state spaces $\mathcal{H}^g$ and $\mathcal{A}$, it is the case only as a measure zero event. Thus, we exclude the possibility of the case from our analysis.

In Appendix A.1, we also show that these two equilibria can be computed by extending Gale and Shapley (1962)'s algorithm. In Section 2.4, we actually compute and estimate an unique M-optimal stable matching equilibrium. Hereafter, we refer to a stable matching equilibrium as an M-optimal stable matching equilibrium.[13]

2.3 The Data

To estimate the equilibrium which we defined in the previous section, we construct state-year panel data from the birth and the marriage records of the CDC's National Vital Statistics Report (NVSR). In this section, we discuss the details of the construction of our variables: the total fertility rate for marital and non-marital births and the marriage rate. We also describe how we create the CSE measures and discuss some other control variables like state characteristics.

2.3.1 Dependent Variables

We use three dependent variables for our main analysis: the total fertility rate (more precisely, the total period fertility rate) for marital births, the total fertility rate for non-marital births, and the marriage rate. For the marital and non-marital total fertility rates, first we calculate age-specific (the mother's age) marital and non-marital birth rates for six age groups for each state and year from the NVSR 1980 - 1997, restricting the mother's age to 15 - 44. And we sum them up and multiply the sum by five. For the marriage rate, we define it as the number of marriages per 15 - 44 year-old female

[13] In this paper, we only analyze the M-optimal stable matching equilibrium. But, there may well exist other stable matching equilibria including the W-optimal stable matching equilibrium. Del Boca and Flinn (2005) explore how much other equilibria could be different from the M-optimal stable matching equilibrium by counting the pairs which exist both in the M-optimal stable and W-optimal matching equilibria. In their case, the same pairs are matched in over 96% of the cases in the male-preferred and female-preferred equilibria. And, they conclude that even though other equilibria exist, they are not so different from the M-optimal stable matching equilibrium. We will leave the application of this stability exercise for our future work.

population.[14] And, we calculate it also from the NVSR (1980 - 1995). The summary statistics for the NVSR: Natality data are in Table 2.2.

Table 2.2: Summary Statistics for National Vital Statistics Report Natality Data, 1980 - 1997

Name		
		Num. of Observations
State-Year Panels		908
Total Number of Births in the Data		69,315,940
Average Number of Births within a Panel		76,339
	Mean	**Std. Deviation**
Age of Mother at Child's Birth	26.19	5.68
Age of Father at Child's Birth	26.78	5.50
Mother's Education	**Num. of Observations**	**% in the Sample**
HS <	13,360,589	19.27
HS =	23,428,527	33.80
HS >	23,463,224	33.85
Mother's Race		
White	55,610,558	79.79
Black	10,940,109	15.78
Ohters	2,765,173	4.43

[14]Although the best measure of the marriage rate would be the number of marriages per non-married population, the stock of (non)-married people is only available for the years in which the decimal U.S. Census has been conducted.

2.3.2 Child Support Enforcement Measures

Our main concern is to analyze how people adjust their marriage and fertility decisions to a change in the cost of non-marital births. Therefore, we think that the aggregate collection rate of child support defined for each state and year is the most suitable measure for our main analysis.[15] The aggregate collection rate is the total amount of child support collected over the total eligible amount of child support. For the numerator, we pick the numbers from the Office of Child Support Enforcement (OCSE) 1980 - 1997 Annual Reports to Congress (U.S. Department of Health and Human Services, 1980 - 1997). For the denominator, we calculate a number from the Current Population Survey (CPS) (U.S. Bureau of Labor Statistics) in the following way.

1. Consider the sample of the married couples. Regress the husband's real annual income on the wife's demographic characteristics and the characteristics of the residential state, age, age-squared, education, ethnicity, whether or not living in a central city, the unemployment rate of the state, and the average income of the state.

2. Predict the income of the single mother's partner from the above regression.

3. Based on the number of children the single mother has, apply the Wisconsin guideline to determine the eligible amount of child support.[16]

[15] One of the difficulties with CSE measures is the possibility of their endogeneity. Case (1998) applies the instrumental variable method by using the percentage of the state's House and Senate members that are women as an instrumental variable and still finds a significant negative impact of CSE on the non-marital birth rate. Miller and Garfinkel (1999) employ the same strategy to control the endogeneity. Without exception, our CSE measures might potentially involve endogeneity. We leave the problem for future work.

[16] The Wisconsin guideline is a "percentage-of-income guideline" in which fathers' child support obligation is 17% of fathers' gross income for one child and 25%, 29%, 31%, and 34% for two, three, four, and five or more children, respectively. This percentage-of-income guideline have been adopted by 15 states, whereas other 31 have adopted variants of an income-shares guideline which takes into account the incomes of both parents when determining the award amount. Garfinkel et al. (1998) examine the two types of guideline and find that state rankings on the collection rate are not sensitive to the guideline used.

4. Calculate the total eligible amount for each state and year by summing up the amount obtained in step 3, and then adjust the population of single mothers in each state to match the numerator by using the Surveillance, Epidemiology, and End Results (SEER) data published by the National Center Institute.

Our result is displayed in Table 2.3. Also in Table 2.3, two other child support enforcement measures are calculated to test the robustness of our estimation result. The first one is the state's expenditure for the child support enforcement policies per single mother.[17] The state's expenditure data are from the OCSE's Annual Reports, and the population of single mothers is calculated from CPS and SEER. The second alternative measure is paternity establishment rate, defined as the number of paternities established for non-marital births over the total number of non-marital births in a given year. The data for the number of paternities established are from the OCSE's Annual Reports. And the data for the total number of non-marital births are from the NVSR.

Table 2.3: Summary Statistics for CSE Measures, 1980 - 1997.

CSE Measures	**1980 Mean**	**1997 Mean**	**1980-1997 Mean**
Collection Rate	4.1 %	18.5 %	10.0 %
Expenditure per Single Mother	2.38	4.14	3.04
Paternity Establishment Rate	20.4 %	55.0 %	36.2 %

(The mean values are calculated across states.)

2.3.3 Other Independent Variables

State average wages of full-time workers and state unemployment rates are included as independent variables in our regression analysis because they potentially affect people's marriage and fertility decisions. The former is from CPS, and the latter is from the Local

[17]The numbers in Table 2.3 are based on 2000 dollars.

Area Unemployment Statistics (LAUS) (U.S. Bureau of Labor Statistics). The gender wage gap as a fraction of the average wage of female full-time workers over the average wage of male full-time workers is also included since it might affect, especially, female's marriage and fertility decisions.[18] Three demographic statistics - the fraction of blacks, the fraction of Hispanics, and the fraction of high-school dropouts - are the other controls considered in the analysis. Finally, previous studies show that generous welfare benefits make single motherhood more affordable and increase the number of non-marital child births (Rosenzweig (1999), Neal (2004)). Thus, we include the generosity measure of state welfare policy. The sum of the maximum amount of the Aid to Families with Dependent Children (AFDC) grant and food stamp benefit is used as this measure.[19] All the monetary values are converted to the 2000 dollar values.

2.4 Structural Estimation

In this section, we describe our econometric methodology to estimate the equilibrium values.

2.4.1 Two-Step Estimation Procedure

We apply simulated method of moment (SMM) to estimate the parameters of the structural model laid out in Section 2. In particular, we apply a two-step procedure similar to that used by Voena (2010). The method is closely related to (but not the same as) the indirect inference method, which is a simulation-based method for estimating the parameters of economic models, first introduced by Smith (1990, 1993) and extended by Gourieroux et al. (1993) and Gallant and Tauchen (1996).[20]

[18] See the work of Regalia et al. (2010), for example.

[19] These data come from the *Overview of Entitlement Program: Green Book* edited by the U.S. House of Representatives, Committee on Ways and Means.

[20] The difference between our method and indirect inference is as follows. In indirect inference, the regressions in the first stage (called an 'auxiliary model') and those in the second stage must be the same. But, in our case, the first-stage regression includes the state fixed effects, the state characteristics, and the state-specific trends, which are not included in the regressions in the second stage. In the indirect

Our method consists of two stages of minimization. In the first stage, we employ the standard fixed effects regression model to obtain the coefficients of the variables of interest to the changes in the CSE measure. In the second-stage regression, we estimate the structural model's parameters by SMM targeting on the coefficients which we obtained in the first stage. More precisely, using reduced-form regressions, first, we estimate the effect of CSE on non-marital and marital total fertility rates and obtain the regression coefficients, $(\hat{\beta}_{\gamma}^{S,Data}, \hat{\beta}_{\gamma}^{M,Data})$. Then, in the second stage, we calculate structural counterparts for $\left(\hat{\beta}_{\gamma}^{S}(\boldsymbol{\theta}), \hat{\beta}_{\gamma}^{M}(\boldsymbol{\theta})\right)$ and estimate a set of structural parameters $\boldsymbol{\theta}$ with other targets $Z(\boldsymbol{\theta})$ by

$$\hat{\boldsymbol{\theta}} = \arg\min_{\boldsymbol{\theta}} \left[\ m(\boldsymbol{\theta})^T \times \mathbf{W} \times m(\boldsymbol{\theta})\right],$$

where $m(\boldsymbol{\theta})$ is a column vector $\left(\hat{\beta}_{\gamma}^{S}(\boldsymbol{\theta}) - \hat{\beta}_{\gamma}^{S,Data}, \hat{\beta}_{\gamma}^{M}(\boldsymbol{\theta}) - \hat{\beta}_{\gamma}^{M,Data}, Z(\boldsymbol{\theta}) - Z^{Data}\right)^T$. Here $\mathbf{W}$ is an arbitrary weighting matrix. The other targets $Z(\boldsymbol{\theta})$ are chosen so that the model captures the important characteristics of the real data, like the total fertility rate or the total educational expenditure in the economy.

As the last step of our estimation, we test our model's performance by predicting the marriage rate. As we have said, the marriage rate has also sharply risen in the states with strict CSE. This increase in marriages is crucial to identify our story from other alternatives. Therefore, we use it as an over-identification device for the estimates obtained from the structural estimation.

2.4.2 First Stage: The Fixed Effects Regression Model

In the first-stage estimation, we use the fixed effects regression model. Moreover, we include state-specific time trends[21] in our benchmark model. Focusing on the period

inference method, even if the independent variables are endogenous in the first-stage regression, one can obtain the consistent estimator in the structural estimation. But, in our case, if the independent variables are endogenous, then the estimated structural parameters are no longer consistent.

[21] The literature includes several discussions on the inclusion of state-specific time trends. Friedberg (1998) talks about the importance of them to measure the impacts of the divorce law reform on the

1980 - 1997, we run the following regressions on the state-year panel data:

$$Y_{s,t}^{S} = \beta_0^S + \beta_1^{S\prime} X_{s,t} + \sum_s \beta_{2,s}^S D_s + \sum_s \beta_{3,s}^S (D_s \times t) + \beta_\gamma^S \gamma_{s,t}$$
$$Y_{s,t}^{M} = \beta_0^M + \beta_1^{M\prime} X_{s,t} + \sum_s \beta_{2,s}^M D_s + \sum_s \beta_{3,s}^M (D_s \times t) + \beta_\gamma^M \gamma_{s,t},$$

In the above regressions, $Y_{s,t}^S$ and $Y_{s,t}^M$ are the total fertility rate for non-marital and marital births in state s in year t. Here $X_{s,t}$ includes the characteristics of state s in year t: the average wage of full-time workers, the state unemployment rate, the gender wage gap, the fraction of black people, the fraction of Hispanic people, the fraction of people without a high-school diploma, and also the measure of the generosity of welfare for single mothers. Here D_s is a state dummy and $(D_s \times t)$ is a state-specific time trend. Finally, $\gamma_{s,t}$ is the three-year moving average of the CSE measure.[22]

2.4.3 First Stage: Results

The results of the first-stage regressions are summarized in Table 2.4. For the non-marital fertility rate, all three CSE measures have negative effects which are significant at the 1% level. Looking at the coefficient for the fraction of black people, you may wonder why it is significantly negative. But this is true when we include the state fixed effects, and other studies are also getting the same result.[23] For marital births, the effects of CSE seem to be a bit weak, but they are still positive at the 10% level for the collection rate measure and positive at the 5% level for the expenditure and paternity establishment rate measures.

divorce rate. In our case, it also turns out to be important, especially for the estimations of the total fertility rate for marital births and the marriage rate. The results without the state-specific time trends are discussed in Section 2.4.5.

[22] We also consider the five-year moving average of the measures in Section 2.4.5, in order to check the robustness of the result.

[23] See the work of Garfinkel et al (2003), for example.

2.4.4 Marriage Rate Regression

We also run the same regression for the marriage rate. The increase in the marriage rate is crucial to identify our story from other alternatives. So we will use this estimate later to check the model's performance. As for the regression result, we find significantly positive effects of CSE (at the 1% level) on the marriage rate for all three CSE measures as summarized in Table 2.5.

Table 2.4: First Stage Regressions: The Total Fertility Rate for Non-Marital and Marital Births

Dependent Variable	Non-Marital Total Fertility Rate			Marital Total Fertility Rate		
CSE Measures (3-Year Moving Average)						
1) Collection	-0.29737**			0.17234†		
	(0.07936)			(0.09502)		
2) Expenditure		-0.01548**			0.00738*	
		(0.00258)			(0.00313)	
3) Paternity			-0.04132**			0.03481*
			(0.01451)			(0.01550)
Average Wage	-0.00014**	-0.00013**	-0.00012**	-0.00008	-0.00008	-0.00009†
	(0.00004)	(0.00004)	(0.00004)	(0.00005)	(0.00005)	(0.00005)
Unemp. Rate	0.00425**	0.00421**	0.00592**	-0.00577**	-0.00570**	-0.00116
	(0.00128)	(0.00126)	(0.00139)	(0.00153)	(0.00153)	(0.00149)
Gender Gap	-0.00723	-0.00548	-0.00674	0.00507	0.00398	0.00467
	(0.01463)	(0.01442)	(0.01440)	(0.01751)	(0.01747)	(0.01538)
Frac. Black	-0.57926**	-0.59053**	-0.50151**	-0.05292	-0.05067	-0.03460
	(0.11592)	(0.11432)	(0.12300)	(0.13878)	(0.13850)	(0.13138)
Frac. Hisp.	-0.25437	-0.23141	0.29846	-1.18736**	-1.19020**	-0.31875
	(0.16167)	(0.15908)	(0.18415)	(0.19355)	(0.19273)	(0.19670)
Frac. HS DP	0.20511*	0.16742†	0.12462	0.17183	0.19072	0.18766†
	(0.09920)	(0.09798)	(0.10492)	(0.11877)	(0.11871)	(0.11207)
Max AFDC	0.04237**	0.04171**	0.07972**	0.02951**	0.03013**	0.07517**
	(0.00370)	(0.00359)	(0.00555)	(0.00443)	(0.00434)	(0.00593)
Intercept	-58.19391**	-56.04314**	-56.52598**	18.04203**	16.54161**	9.01692
	(4.96011)	(4.75847)	(5.45825)	(5.93830)	(5.76504)	(5.83009)
State-Specific						
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Trends	Yes	Yes	Yes	Yes	Yes	Yes
N	908	908	806	908	908	806
R^2	0.95963	0.96069	0.96057	0.97126	0.97135	0.97615
F	174.02847	178.92167	155.563	247.45659	248.18175	261.29123

Significance levels : † : 10% $*$: 5% $**$: 1%

(Standard errors are in parentheses.)

Table 2.5: Marriage Rate Regressions

Dependent Variable	Marriage Rate		
CSE Measures (3-Year Moving Average)			
1) Collection	0.01315**		
	(0.00419)		
2) Expenditure		0.00061**	
		(0.00015)	
3) Paternity			0.00302**
			(0.00076)
Average Wage	0.00018	-0.00025	0.00041†
	(0.00024)	(0.00023)	(0.00023)
Unemp. Rate	-0.00047**	-0.00046**	-0.00028**
	(0.00006)	(0.00006)	(0.00006)
Gender Gap	-0.00211	-0.00186	-0.00014
	(0.00226)	(0.00224)	(0.00228)
Frac. Black	0.00873	0.00853	0.00536
	(0.00581)	(0.00577)	(0.00605)
Frac. Hisp.	-0.01984	-0.01995	-0.01791
	(0.01275)	(0.01266)	(0.01317)
Frac. HS DP	0.00148	0.00292	0.00300
	(0.00481)	(0.00480)	(0.00500)
Max AFDC	-0.00077**	-0.00074**	0.00027
	(0.00018)	(0.00017)	(0.00029)
Intercept	2.27407**	2.16429**	1.97683**
	(0.24523)	(0.23862)	(0.26663)
State-Specific			
Fixed Effects	Yes	Yes	Yes
Trends	Yes	Yes	Yes
N	681	681	591
R^2	0.96773	0.96814	0.97179
F	180.25471	182.62504	184.0761

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

(Standard errors are in parentheses.)

2.4.5 First Stage: Checking the Robustness

In this subsection, we briefly talk about the robustness of our first-stage estimation results. Details are available in Appendix A.2.

Five-Year Moving Average of the CSE Measures

Since we have been taking only three-year moving averages of the CSE measures, it might be true that the dependent variables react too much to the change in the degree of CSE in the short term. In the long run, stronger CSE might affect the dependent variables more modestly. To check if that is true or not, we also consider the five-year moving averages of the CSE measures and run the same regressions. The results are summarized in Appendix A.2. As shown there, the five-year moving averages of the measures increase the effects of stronger CSE on the dependent variables. Therefore, we conclude that the CSE effects do not disappear even if we consider the longer time period. (They last for at least 5 years.)

The Regressions without State-Specific Time Trends

Through our first-stage estimation, it turns out that the state-specific time trends, which we include in our bench-mark regressions, are important to capture the correct effects of stronger CSE on the dependent variables (In particular, for the marital total fertility rate and the marriage rate). To emphasize this point, we show the regression results without the state-specific time trends in Appendix A.2. In those regressions, instead, we include an aggregate time trend with standard state dummies. As you see in the tables, the results of the non-marital total fertility do not change signs or significance. However, the results of the marital total fertility do change signs. And for the marriage rate, the results become no longer significant. Friedberg (1998) talks about the importance of state-specific time trends in her divorce rate regression. She reports that the effects of the divorce law reform on the divorce rate could not be observed without including state-specific time trends in the regression. That applies to our analysis as well.

2.4.6 Second Stage: Structural Estimation

Now we turn to the second-stage regression, where we estimate the structural model's parameters. In this subsection, we talk about the parameters, the moments to match, and the estimation procedure in our second-stage estimation.

Parametrization

First, let us assume the following functional forms for utility and child investment functions.

$$u(c, a') + v(nq) = \ln(c) + a' + \alpha \ln(nq)$$
$$f_0(s) = (\iota + s)^{\eta_0}, f_1(s) = (\iota + s)^{\eta_1} \quad 0 < \eta_0, \eta_1 < 1.$$

These functional forms give us five parameters to be estimated, $(\alpha, \iota, \eta_0, \eta_1, \psi)$. Also, we assume that people's charm is normally distributed, with mean 0 and variance σ_a^2 for both women and men; $a \sim N(0, \sigma_a^2)$, Then σ_a is another parameter to be estimated. Other parameters determined through estimation are δ: utility discount for fathers out of wedlock, κ: utility value of marriage, and ψ: good cost per child. Then we end up with eight parameters to be estimated. We list them in Table 2.6. Other parameters in the model can be exactly identified from the data. Those are summarized in Table 2.7 and discussed below.

Table 2.6: Parameters to be Estimated in the Second Stage

Name	in Model
Uitlity Discount for Fathers out of Wedlock	δ
Utility Value of Marriage	κ
Variance of People's Charm	σ_a
Parameter for Utilility Weight	α
Parameter for Child Investment Function	ι
Parameter for Child Investment Function (Non-Marital)	η_0
Parameter for Child Investment Function (Marital)	η_1
Goods Cost per Child	ψ

Table 2.7: Exactly Identified Parameters

Name	Symbol	Value	Source
AFDC Benefit (1980)	$g(e,n)$	0.81×(Poverty Threshold)	Congressional Green Book
Child Support Order	$\tau^{cs}(n)$	$0.17 \sim 0.31$	Wisconsin Guideline
Time Cost for Children	ϕ	0.075	De La Crox et al. (2003)
Women's Mean Wage	μ_h^f	2.20	Greenwood et al. (2003)
Men's Mean Wage	μ_h^m	2.58	Greenwood et al. (2003)
Log Var. of Wages	σ_h	0.57	Greenwood et al. (2003)

Aid to Families with Dependent Children (AFDC) Eligibility and benefit levels of AFDC vary across states and time periods. In order to simplify this criteria, we assume that the maximum AFDC benefit is 81% of of the Federal poverty threshold, where the number (81%) comes from the average eligibility criteria across states in 1980.[24] We also assume that if a single mother's income is below the poverty threshold, the portion is compensated by the AFDC benefit, so that her income is equal to

[24]This data come from the *Overview of Entitlement Program: Green Book* edited by the U.S. House of Representatives, Committee on Ways and Means.

the one at the poverty threshold. This poverty threshold is set as $0.27\times$(Men's mean income) calculated from the 1980 data.[25] The poverty line increases by 25% every time a household gets an additional member.

Child Support Order We follow the Wisconsin guideline to determine the eligible amount of child support. The guideline says 17% of a payer's income if there is only one child, 25% for two children, 29% for three children, 31% for four children, and 34% for five or more.

Time Cost for Children We follow De La Croix and Doepke (2003) to determine the time cost for children. Based on their calculation, parent spends 7.5% of time per child in parent's entire life.

Human Capital Distribution We follow Greenwood et al. (2003) to determine the human capital distributions for women and men. They assume log-normal distributions for human capital and match their mean and standard deviation to the wage data. More precisely, they assume that women's human capital level h^f follows a log-normal distribution with its parameters $\mu_h^f = 2.20$ and $\sigma_h = 0.57$. For men, they assume the parameters $\mu_h^m = 2.58$ and $\sigma_h = 0.57$. When computing the model, we discretize those distributions so that each type has the same number of people as we assumed in Section 2.2.1.

[25] See the website; http://www.census.gov/hhes/www/poverty/data/threshld/.

Table 2.8: Targeted Values in the Second-Stage Estimation

Name	**Value**	**Data Source**
(1) Regression Coefficient for Non-Marital Births: β^S	-0.297	First Stage Regression
(2) Regression Coefficient for Marital Births: β^M	0.172	First Stage Regression
(3) 1980: Fraction of Non-Marital Births in Total Births	0.162	NVSR (1980)
(4) 1980: Total Fertility Rate	1.887	NVSR (1980)
(5) 1980: Total Educational Expenditure in Cons. Exp.	0.104	U.S. Dept. of Education
(6) 1980: Fertility Ratios Between		
Non-Married and Married	0.727	NSFG (1979)
(7) 1980: Educational Investment Ratio Between		
Non-Married and Married	2.764	U.S. Bureau of Labor Stat.
(8) 1980: Income Correlation among Married	0.440	CPS (1980)
(9) Fraction of Child's Consumption		
in Married Household with One Child (OECD)	0.147	

Moments

Listed in Table 2.8 the eight moments in the second-stage estimation. The seven parameters are thus over-identified. The regression coefficients for (1) the non-marital and (2) marital total fertility rates, (β^S, β^M), and (3) the fraction of non-marital births are the most crucial targets, which identify (δ, κ). (4) The total fertility rate, (5) the total educational expenditure,[26] (6) the fertility ratio between the non-married and the married, and (7) the educational investment ratio between the non-married and the married jointly determine the four parameters, $(\alpha, \iota, \eta_0, \eta_1)$.[27] (8) The fraction of child's consumption in married household with one child identifies ψ: good cost per child. (9) The income correlation among married couples determine σ_a. In the model, all the statistics (3) - (9) are calculated in the equilibrium in which CSE $\gamma \approx 0$. That is, assuming that CSE is very small in 1980, we calculate the model's counterparts for the pre-CSE

[26] *Digest of Education Statistics*, edited by the Office of Educational Research and Improvement, U.S. Department of Education.

[27] The fertility ratio between the non-married and the married is calculated from the CDC's National Survey of Family Growth (NSFG) 1976. The educational investment ratio between the non-married and the married is calculated from *Household Expenditure on Children 2007-2008* in *the Monthly Labor Review*, U.S. Bureau of Labor Statistics.

targets.

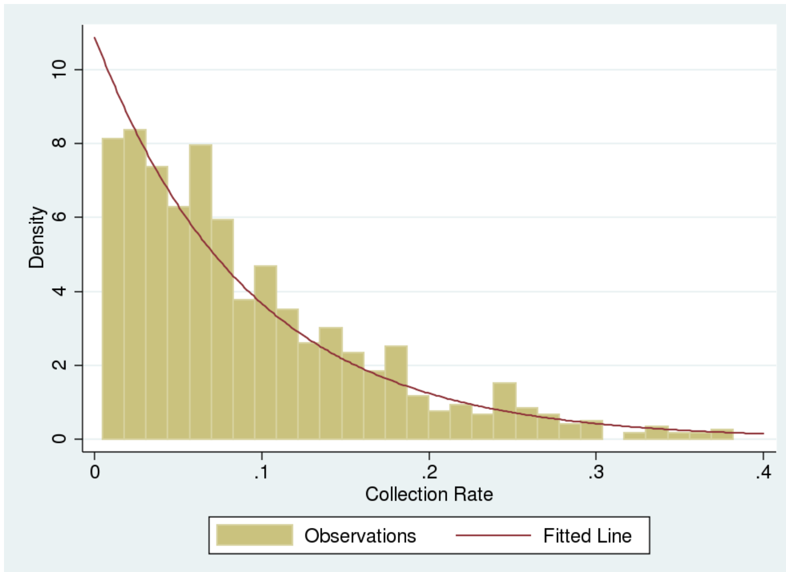


Figure 2.4: Distribution of Child Support Collection Rate, 1980-1997

Second-Stage Estimation Procedure

In the second-stage estimation, we simulate the model, run regressions, and obtain the model's counterpart for the regression coefficients $(\hat{\beta}_\gamma^S, \hat{\beta}_\gamma^M)$. In order to run this simulation, we first need to approximate the distribution of the child support collection rate in order to draw random policy values $\{\gamma_t\}$. Figure 2.4 shows such an approximation. The distribution of the collection rate is replicated by an exponential distribution with the same mean as in the data. Then we run the second-stage estimation by taking the following steps.

1. In every loop in the estimation, simulate the policy from the exponential distribution 908 times, $\{\gamma_t\}_{t=1}^{908}$. This is the actual number of the state-year observations in the first-stage regression.

2. Then, given a set of parameters $\boldsymbol{\theta}$, compute the equilibrium for each given γ_t. In particular, when computing the equilibrium, we follow the steps below.

(a) Discretize the spaces for human capital and charm.

(b) After calculating $\left\{\hat{V}_S^f(\Phi,\gamma_t), \hat{V}_S^m(\Phi,\gamma_t), \hat{V}_M^f(\Phi,\gamma_t), \hat{V}_M^m(\Phi,\gamma_t)\right\}_{\Phi\in\mathcal{F}}$ that are the utility values for all possible pairs, apply the extended version of Gale and Shapley's algorithm as described in Appendix A.1. Compute the distribution of the pairs in non-marital relationships and marital relationships. Then calculate the total fertility rate in each relationship.

3. Run the following regressions for the obtained marital and non-marital total fertility rates for each of $\{\gamma_t\}_{t=1}^{908}$.

$$Y_t^S = \beta_0 + \beta^S(\boldsymbol{\theta})\gamma_t$$
$$Y_t^M = \beta_0 + \beta^M(\boldsymbol{\theta})\gamma_t.$$

4. Construct other targets, $Z(\boldsymbol{\theta})$, and evaluate the model's performance by calculating

$$m(\boldsymbol{\theta})^T \times \mathbf{W} \times m(\boldsymbol{\theta})$$

where $m(\boldsymbol{\theta}) \equiv \left(\hat{\beta}_\gamma^S(\boldsymbol{\theta}) - \hat{\beta}_\gamma^{S,Data}, \hat{\beta}_\gamma^M(\boldsymbol{\theta}) - \hat{\beta}_\gamma^{M,Data}, Z(\boldsymbol{\theta}) - Z^{Data}\right)$.

5. Repeat steps 1 - 4 until the set of parameters attains the minimum of the above objective.

In the computation of the model, we discretize the state space for human capital and charm using 20 and 5 grids, respectively. Thus, there are 100 types of women and men in the economy.

2.5 Results

In this section, we talk about our estimation results. We also derive the CSE's implications for the next generation's income distribution.

2.5.1 Estimation Result

The model's performance and the estimation result for the parameters are summarized in Table 2.9 and Table 2.10. In Table 2.9, as you see in the data and model columns, our model is performing well; it closely matches most of the targets in the data including the coefficients, β_γ^S and β_γ^M. One exception is the fraction that educational expenditures are of the total consumer expenditures. In the data, education is about 10% of total consumer expenditures, but the model suggests about 20%. One possible explanation for this difference is the lack of public education in the model. If we include this amount, the model might perform better.

In the model, men's increased willingness to marry is the driving force behind the decrease in non-marital births ($\beta_\gamma^S < 0$) and the increase in marital births ($\beta_\gamma^M > 0$). After the strengthening of CSE policies, facing the larger cost per child due to the mandatory child support payment, men in non-marital relationships may

1. Reduce the number of children and, instead, increase investments in child quality.
2. Reduce the number of children and, instead, increase the private consumption.
3. Get married to avoid the child cost change.

Option (1) is not attractive to unmarried fathers, because to increase a child's quality investment they have to transfer money to the mothers. But these transfers involve two types of inefficiency in our model: First, in non-marital relationships, since the mothers are not considering the fathers' utility, they do not invest all the money in children's quality. They use some of it for their private consumption. Second, if the mother in a non-marital relationship is on a welfare program, then the state government takes away a significant portion of child support payments made by the biological father. Therefore, fathers' investments do not really increase a child's quality. And unmarried fathers are thus left with options (2) or (3). As a result, men split between reducing the number of children and increasing marriage when facing the increased degree of CSE. This result hinges upon the parameter, δ.

Table 2.9: The Match Between the Model and the Data

Name	**Data**	**Model**
(1) Regression Coefficients for M Births: β_γ^S	-0.297	-0.272
(2) Regression Coefficients for NM Births: β_γ^M	0.172	0.169
(3) 1980: Fraction of Non-Marital Births in Total Births	0.162	0.170
(4) 1980: Total Fertility Rate	1.887	1.899
(5) 1980: Total Educational Expenditure in Cons. Exp.	0.104	0.182
(6) 1980: Fertility Ratios Between Non-Married and Married	0.727	0.699
(7) 1980: Educational Investment Ratio Between Non-Married and Married	2.764	2.566
(8) 1980: Income Correlations among Married	0.440	0.434
(9) Fraction of Child's Consumption (OECD)	0.147	0.140

Table 2.10: Estimated Parameters

Name	**Parameter**	**Estimates**
Uitlity Discount for Fathers out of Wedlock	δ	0.491
Utility Cost of Marriage	κ	-0.185
Parameter for Utilility Weight	α	3.900
Parameter for Child Investment	ι	0.814
Parameter for Child Investment (Non-Marital)	η_0	0.251
Parameter for Child Investment (Marital)	η_1	0.610
Variance of People's Charm	σ_a	0.128
Goods Cost per Child	ψ	1.125

2.5.2 Over-Identification: Model's Performance for Marriage

We check the model's performance through its prediction for the increase of marriages after CSE strengthens. We calculate the changes in the number of the ever-married at age 45 after 10% increase in the collection rate by using the estimated coefficient for the marriage rate from the previous regression. According to our estimate in Table 2.5, a 10% gain in the collection rate will increase the marriage rate by 0.0013 points. (Using the 1980's average marriage rate, 0.042, this turns out to be a 3.1% increase of the marriage rate) If we calculate the number of the ever-married using the marriage rate in 1980 and the one after the 10% increase of the collection rate, the change from the former to the latter is about 1.93%. And, the change in the model is 1.39%. Thus, the model accounts for 72% of the increase in the ever-married in the data, which implies a good performance of our model to account for the changes. (See Table 2.11)

Table 2.11: Model's Performance for the Increase of Marriage

	Num of Ever-Married (Data)	**Num of Ever-Married** (Model)
1980	0.940	0.860
CSE Δ10%	0.958	0.871
Change	Δ1.93%	Δ1.39%

2.5.3 The Effects of CSE on Child Investment and Individual's Welfare

Next, we use the model to quantify the effects of CSE on child investment and individual's welfare. In 2.12, we calculate the changes in the amount of child investment, the quality of child, and the number of child after 10% increase in the collection rate. As found in the table, CSE increases the amount of child investment significantly among the bottom-income group. This change is driven by the change in people's marital status. As more couples start getting married, they pool their income together, and access to the better child investment technology, which results in the increase in child investment.

Table 2.12: The Changes in Child Investment After a 10% Increase in the Collection Rate

Mother's Income Group	**Child Investment** Δs	**Child Quality** Δq	**Number of Child** Δn
Top 0-20 %	-Δ0.1%	-Δ0.1%	+Δ0.0%
20-40 %	-Δ0.1%	-Δ0.1%	+Δ0.0%
40-60 %	+Δ0.0%	+Δ0.0%	+Δ0.0%
60-80 %	+Δ1.1%	+Δ0.9%	-Δ0.5%
80-100 %	+Δ5.0%	+Δ4.8%	-Δ2.0%
Average	+Δ1.2%	+Δ1.1%	-Δ0.5%

Table 2.13 shows the associated changes in the number of the married, and women and men's welfare after 10% increase in the collection rate. As shown in the table, more people start getting married, especially, in the bottom-income group of people. This is caused by the men's increased willingness to marry; the mechanism we talk in the previous sections. And, that change of the increase in marriage is the driving force behind the increase in child investment.

Table 2.13 shows the changes in individual's welfare by income level. You will notice that there are significant transfers of utility from men to women even in the high-income groups of people. This is because women obtain more consumption within household after men's outside option values (the values of being single) decrease. This effect is not quite strong for women in the bottom-income group since not all the women in that group get married after 10% increase in the collection rate. Most of those unmarried women are on the welfare program (AFDC), and thus, they cannot enjoy the child support transfers from men because the government takes them away.

Table 2.13: The Changes in Marriage and Individual's Welfare After a 10% Increase in the Collection Rate

	Marriage		Welfare	
Income Group	**Women**	**Men**	**Women**	**Men**
Top 0-20 %	-Δ0.0%	-Δ0.0%	+Δ2.6%	-Δ2.2%
20-40 %	-Δ0.0%	-Δ0.0%	+Δ2.6%	-Δ2.2%
40-60 %	+Δ0.0%	+Δ0.0%	+Δ2.7%	-Δ2.3%
60-80 %	+Δ2.5%	+Δ0.0%	+Δ3.0%	-Δ2.5%
80-100 %	+Δ5.0%	+Δ7.5%	+Δ1.5%	-Δ5.1%
Average	+Δ1.5%	+Δ1.5%	+Δ2.5%	-Δ2.9%

2.5.4 Inter Generational Human Capital Transmission

Finally, we look into the changes in the next generation's income distribution. Assume human capital in the next generation is log-normally distributed around child quality. The conditional mean is $\mu^f_{h|q}$ and $\mu^m_{h|q}$, and conditional variance, $\sigma_{h|q} = \sigma_g$:

$$\begin{aligned} \mu^f_{h|q} &= \log\left(\epsilon_1 \times q^{\epsilon_2}\right) \\ \mu^m_{h|q} &= \log\left(\epsilon_1 \times q^{\epsilon_2} + \mu_g\right). \end{aligned}$$

To predict the next generation's income distribution, we first calibrate the parameters $(\epsilon_1, \epsilon_2, \sigma_g, \mu_g)$ so that (1) human capital distribution in the next generation is the same as in the previous generation in 1980, and (2) the correlation between son and father's income is $\rho_g = 0.73$ (Knowles (1999)). Then we use those human capital transmission functions to generate the next generation's income distribution. The calibration result of $(\epsilon_1, \epsilon_2, \sigma_g, \mu_g)$ is summarized in Appendix A.3.

Table 2.14 and Table 2.15 summarize the result of a 10% increase in the child support collection rate. Our model predicts that assuming a general human capital transmission function, the model predicts that the increased collection rate will increase people's income, especially, in the bottom group, and decrease the 90-10% income ratio of the next generation by 3.1%.

Table 2.14: The Changes in Income After a 10% Increase in the Collection Rate

Income Group	**Men's Income in the Next Generation** Δwh^m
Top 0-20 %	$+\Delta$0.0%
20-40 %	$+\Delta$0.1%
40-60 %	$+\Delta$1.3%
60-80 %	$+\Delta$1.7%
80-100 %	$+\Delta$3.0%
Average	$+\Delta$1.22%

Table 2.15: The Changes in Income Distribution After a 10% Increase in the Collection Rate

Name	**Before**	**After**	**Changes**
Men's 90-10 Income Ratio	1.963	1.904	-Δ3.1%
Men's Gini Coefficient	0.348	0.345	-Δ0.8%

2.6 Conclusion

In this paper, we have analyzed the effects of the strengthened U.S. Child Support Enforcement policies on people's marriage and fertility decisions and long-term inequality. Despite their original purposes, the CSE policies have brought unexpected changes in people's marriage and fertility behaviors. Based on our new empirical findings, we propose a mechanism which accounts for the changes of non-marital births, marital births, and the marriage rate. We develop a novel stable matching model which features the choices of marital or non-marital relationships, and structurally estimate the model using the CDC's National Vital Statistics Report Natality data. Our results show that strengthened CSE increases child investment through secondary effect; the shift from non-marital births to marital births. And our model predicts that there will be a significant reduction in the poverty in the next generation through this change.

Chapter 3

The Blighted Youth: An International Comparison of Life-Cycle Unemployment

3.1 Introduction

Across advanced OECD economies, youth unemployment rates are typically at least double those of adult unemployment rates and are more sensitive to business cycle fluctuations. Bell and Blanchflower (2011), for example, estimate that youth unemployment rates change 1.79 percentage points for each 1 per cent change in adult rates. The large negative and long-lasting effects on earnings for young workers of entering the labor market in a downturn have been well documented (discussed below). In countries like Spain and Greece, where the unemployment rate for workers of age 15-24 has recently surpassed 50%, the welfare implications are potentially large.

The purpose of our study is to evaluate the costs of recessions and, in particular, the long lasting effects on young workers entering the labor market during a downturn[1].

[1] Standard models of search and unemployment, in the Diamond-Mortensen-Pissarides (DMP) tradition, are not able to generate earnings losses comparable to those found in the data (Davis and von

To this effect we build an heterogeneous worker life-cycle model of unemployment with on-the-job human capital accumulation and aggregate productivity shocks[2]. We are interested the quantitative role of the tax-wedge and minimum wages in determining the impact of recessions on unemployment rates across countries.

The quantitative model builds upon the theoretical work of Guido Menzio and Shouyong Shi (2010a, 2010b, 2011). They develop a framework of directed job search and free entry of firms. The main advantage of this framework is the nature of the resulting *block recursive equilibrium*: value and policy functions of agents are independent of the endogenous distribution of workers across individual states (in our version they will depend on the aggregate state of the economy only through the realization of the aggregate productivity state). This framework is thus particularly useful due to its tractability for analyzing the effect of aggregate productivity shocks on the labor market.

Most closely related to our paper is Menzio et al. (2012). They study a life-cycle model with on-the-job human capital accumulation, search and learning frictions and use this theory to decompose the life-cycle profile of wages, transition rates and productivity into the effects of age variation in work-life expectancy, human capital and match quality.

Our interest is on the interaction of recessions and labor market institutions, the tax-wedge and minimum wages in particular. Therefore we introduce aggregate productivity shocks. To consider labor market institutions we modify the wage determination process from Menzio et al. (2012). In our model the market where a worker decides to search is indexed by ability, age, human capital and the wage paid in the first period. If the match is maintained posterior wages are determined through a Nash-bargaining process.

We also extend the model by introducing heterogeneous ability of workers. Huggett,

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Wachter, 2011).

[2]We abstract from welfare losses associated with incomplete markets for risk sharing. Rogerson and Schindler (2002) asses the welfare costs of the risk of job displacement, associated with large persistent losses in income. They abstract from heterogeneity in idiosyncratic wage growth (other than that generated by a displacement shock) and from labor market frictions that affect the outcomes experienced by workers.

Ventura and Yaron (2006) exploit a life-cycle model of human capital accumulation to replicate the age dynamics and cross-sectional properties of the US earnings distribution. They find that differences in the ability to accumulate human capital are essential to reproduce an increase in earnings dispersion over the life cycle and that these differences account for the bulk of the variation in the present value of earnings across agents. Huggett et al. (2011) find that as of age 23, heterogeneity in initial conditions in terms of human capital and learning ability (capacity to accumulate human capital) is the main source of variation in realized lifetime earnings[3], as opposed to shocks received over their lifetime. There is evidence from the literature on recessions and youth unemployment that low ability young workers suffer larger losses than higher ability young workers. Furthermore, since these workers will not be able to accumulate human capital, it may affect the persistence of unemployment rates. Workers with less education typically have higher unemployment rates and these rates are more sensitive to business cycle fluctuations.

In our quantitative framework we find that youth unemployment rates are higher and more sensitive to increments in the tax-wedge relative to total unemployment rates. We then simulate one time shocks to aggregate productivity and compare the evolution of unemployment rates in economies with different tax-wedges. We provide estimates of losses in terms of present discounted value of earnings to young workers in different aggregate states of the economy.

The rest of the paper is organized as follows: Section 3.2 discusses the literature on the impact of recessions on young workers entering the labor market, Section 3.3 provides a brief overview on the empirical evidence and theoretical work on different institutions and policies and labor market outcomes, Section 3.4 and Section 3.5 describe

[3]Their choice of age is given by the observation that many people will have finished formal schooling. We note that the literature that estimates the impact of youth unemployment on lifetime/long-term earnings considers the range 16/18 to 25 (discussed below). Huggett et al. (2011) calibrate the initial conditions in terms of human capital as exogenous. Admittedly, as those authors recognize, pushing back the age will raise the issue of the importance of one's family or, more broadly, one's environment. We leave that as a topic for further research.

our theoretical framework and the nature of the block recursive equilibrium, Section 3.6 consists of a discussion of the parameters as well as the quantitative analysis of the model, Section 3.7 concludes with final comments.

3.2 The Long-Term Impact of Recessions on Youth

Entering the labor market during a recession has a large negative and persistent impact on the labor earnings of the young[4]. Unemployment generates a direct loss of income but there are additional large and long lasting effects that represent costs above the direct cost. The literature is too vast for a complete review, but a set of the main results is presented, with a focus on the evidence for advanced OECD economies[5].

The general consensus is that an unemployment spell consistently imposes a persistent wage *scar* upon individuals both in terms of income and posterior unemployment spells (Arumpalam, 2001; Gregg and Tominey, 2005). It is also known that recessions are associated with relatively large increases in unemployment for the young and those with low education (Genda et al., 2010; Bell and Blanchflower, 2011).

Although not focusing on recessions, Kletzer and Fairlie (2003) estimate the long-term costs of job displacement for young adults: five years after a job loss the shortfall in annual earnings is 9% lower for men relative to what would have been expected absent the job loss. For older workers total losses largely represent immediate earnings losses whereas for young workers the loss of opportunities for rapid earnings growth is more important (they find that young displaced workers do not experience a large decline in earnings following displacement). For young workers, substantial costs may be associated with job displacement in the form of missed or delayed opportunities to

[4]Youth is defined as age over the minimum school-leaving age (typically 16-18 for OECD countries) and less than 25 (Bell and Blanchflower, 2011).

[5]We abstain from comparing these estimations across countries. The wide differences in labor market institutions, educational systems, demographic environments, data availability and applied methodologies make any attempt to compare the estimates an uninteresting exercise (this is a point already made in the literature). A discussion of the statistical techniques employed in the literature is outside the scope of this paper.

accumulate human capital.

Kahn (2010) analyzes the labor market experience of those graduating from college as a function of macroeconomic conditions in the US. She estimates an initial wage loss of 6-7% for a 1 percentage point increase in the unemployment rate measure and even 15 years after college graduation the loss is 2.5% and statistically significant.

Table 3.1: The Long-Term Impact of Recessions on Youth

country	earn. loss	period/lag	exercise (*shock*)
Austria	6.5%	accumulated	1 p.p. unemp. rate increase
Canada	5%	accumulated	5 p.p. unemp. rate increase
Japan	5-7%	12 yrs. later	1 p.p. unemp. rate increase
USA	2.5%	15 yrs. later	1 p.p. unemp. rate increase
Sweden	17%	5 yrs. later	50 days youth unemployment
UK	10%	at age 42	6 months+ of youth unemp.

Source: Brunner and Kuhn (Austria, 2010), Oreopoulos et al. (Canada, 2012), Genda et al. (Japan, 2010), Nordström Skans (Sweden, 2004), Gregg and Tominey (UK, 2005), Kahn (2010, USA).

For Canada, Oreopoulos et al. (2012), also considering those graduating from college, estimate that a rise in unemployment rates by 5 percentage points implies an initial loss in earnings of about 9 percent that halves within 5 years and finally fades to zero after 10 years. The role of heterogeneity is also emphasized: advantaged graduates (at the top of the wage distribution) suffer less as they recover within 2-4 years through a process of mobility towards better firms, while earnings of less advantaged graduates can be permanently affected by cyclical downgrading. The least advantaged suffer a loss of 8 percent of cumulative earnings in their first 10 years, double those of the median graduate. The effects of a recession are strongest for young workers, relative to workers with more experience.

For Austria, Brunner and Kuhn (2010) estimate the effects of labor market entry conditions on wages of males entering the labor market and find that a one percentage point increase in the initial local unemployment rate is associated with an approximate shortfall in lifetime earnings of 6.5 percent (average of the accumulated wage losses within the first 20 years of labor market experience). For Japan, Genda et al. (2010) estimate that a one percentage point rise in the unemployment rate at entry reduces the likelihood of being employed by 3-4 percentage points for over 12 years. The same event leads to earnings losses of 5-7% for over 12 years for those without college education. Moreover, a recession at the time of entry not only lowers annual earnings but also raises the likelihood of nonemployment and part-time employment for the less educated. A considerable part of the negative on earnings is the effect through lower likelihood of regular stable employment.

For the UK, Gregg and Tominey (2005) estimate the *scar* from early unemployment to be approximately 10% at age 42 for having over 6 months of youth unemployment if individuals avoid repeat exposure to unemployment. The negative impact is approximately twice as large if the effect on repeated unemployment is taken into account. Early individual unemployment experiences significantly raise the propensity to adult unemployment (see also Gregg, 2001). The role of heterogeneity is emphasized (see also Burgess et al., 2003). The literature in general stresses the importance of heteorgeneity[6] associated with education and ability of the young workers. Individuals securing better qualifications on leaving full-time education are less prone to youth unemployment. This suggests that education can help youths recover from early unemployment but it is not commonly undertaken.

For Sweden, Nordström Skans (2004) estimate that 50 days of unemployment in the year following high school graduation leads to a 3 percentage points higher probability to experience a similar period of unemployment and a decrease in total annual earnings of 17% 5 years later. In Norway, Raaum and Røed (2006) find that individuals who face depressed local labor markets (6% local unemployment rate vs. 1%) when they graduate from secondary education, are subject to relatively high rates of non-employment during

[6]This is not without econometric challenges: identifying causal effects of past unemployment is a difficult task due to unobserved heterogeneity.

their whole prime-age work career.

The severity of long term income losses depend on the business cycle: Davis and von Wachter (2011) estimate that in present value terms men lose on average 1.4 years of pre-displacement earnings if displaced in mass-layoffs events that occur when the national unemployment rate is below 6 percent. This loss doubles to 2.8 years of pre-displacement earnings if the event occurs when the unemployment rate exceeds 8 percent.

A number of theories can potentially predict persistent negative effects from unemployment (see Gregg and Tominey, 2005). An unemployment spell can lead to the depreciation of general skills[7] and the loss of firm specific skills. For those entering the labor market, time without a job is time forgone in terms of human capital accumulation. Theories of on-the-job search will predict that displacement from a *high quality* match implies a higher probability of return to a *low quality* position. Therefore, losses may not solely be due to human capital depreciation. For young workers, mobility plays an important role as it contributes to early wage growth[8]. Theories of screening have also been considered as mechanisms that are able to generate persistent income losses from unemployment. Michaud (2012) provides a theory of information and labor markets with search and matching to account for persistent wage losses of laid-off workers. In this set-up employer uncertainty about unemployed workers' abilities can account for 71% of the long-term wage losses following a lay-off.

We note also that some of these studies estimate the losses suffered by individuals who had unemployment spells, while others refer to losses for those entering the labor market in a downturn but did not experience unemployment. The main channel considered in our theory is through on-the-job human capital accumulation and depreciation. In a recession, youth unemployment rates are higher. Young workers without a job

[7] More generally, unemployment spells are also associated with declines in health and general well-being (Bell and Blanchflower, 2011; Davis and von Wachter, 2011).

[8] There is a sizable literature analyzing the sources of life-cycle wage growth. To mention a recent example, Bagger, Fontaine, Postel-Vinay and Robin (2013) construct and estimate an equilibrium job search model with human capital accumulation, employer heterogeneity and individual level shocks. Career wage growth is decomposed into the contributions of human capital and job search: typically considered the two main driving forces of the earnings/experience profile.

are unable to accumulate human capital, affecting their long term income prospects. Additionally, workers that lose their jobs lose a part of their human capital.

3.3 Policies and Labor Markets

This section provides brief overviews of recent empirical evidence and theoretical work, with a focus on OECD economies.[9]

Table 3.2: Unemployment Rate Equations

	total (male)		**youth (male)**	
tax wedge	0.28***	0.21***	0.45***	0.34***
union density	-0.06***	0.03	-0.11***	0.04
employment protection	-0.55*	-0.50	0.51	-0.38
high corporatism	-1.14***	-1.43***	-1.17	-1.73**
avg. replacement rate	0.14***	0.09***	0.15***	0.08*
output gap	-0.50***	–	-0.98***	–
tfp shock	–	-10.99***	–	-27.44***
terms of trade	–	18.51***	–	33.86***
interest rate	–	0.16***	–	0.26***
labor demand	–	17.60***	–	33.87***
country controls	yes	yes	yes	yes
time controls	yes	yes	yes	yes
R-squared	0.89	0.88	0.90	0.89
n. observations	405	372	404	371

Stat. significance: *** 1%, ** 5%, * 10%.
Source: Bassanini and Duval (2006), World Development Indicators.

The *tax wedge* is defined as the difference between the gross labor costs to employers and the consumption wage paid to employers, i.e. the wage after deduction of direct and indirect taxes, including payroll taxes, income taxes and consumption taxes (Addison

[9] Addison and Teixeira (2001) survey the literature on the labor market consequences of employment protection legislation. They conclude that the preponderance of the studies support the hypothesis that stricter employment protection rules result in lower employment-population ratios. There is, however, no consensus with respect to the effect on unemployment rates. See also Bassanini and Duval (2006) and Nickell et al. (2005). The ambiguous impact of firing costs is also found in the theoretical literature (see Ljungqvist, 2002).

and Teixeira, 2001). Nickell et al. (2005) estimate that a 10 percentage point increase in total employment tax rate leads to approximately a 1 percentage point increase in unemployment in the long run. They also find that changes in labor market institutions explain approximately 55% of the rise in European unemployment from the 1960s to the first half of the 1990s, much of the remainder being due to the deep recession in the latter period. They estimate that changes in the benefit system and increases in labor taxes contribute the most to the increase of 6.8 percentage points in unemployment in this period: the combination of benefits and taxes are responsible for two thirds of the part of the long-term rise in European unemployment that the considered institutions explain (see also Nickell and Layard, 1999).

In line with these findings, Bassanini and Duval (2006) estimate that changes in labor market institutions can account for two-thirds of non-cyclical unemployment changes in OECD countries. In particular, they estimate that a 10 percentage point reduction in the tax wedge would be associated with a drop in the unemployment rate by 2.8 percentage points. They also conclude that the level and duration of unemployment benefits have a significantly positive impact on unemployment. We re-estimate their specifications using male unemployment rates. For a 10 percent point reduction in the tax wedge the total male unemployment rate increases by 2.1-2.8 percentage points, the youth unemployment rate increases by 3.4-4.5 percentage points (Table 3.2). Youth unemployment rates are more sensitive to different types of macroeconomic shocks.

There is work examining the interaction of labor market institutions with the business cycle. Bernal-Verdugo et al. (2012b). estimate a large negative impact of financial crises on unemployment, finding that the effect is less pronounced in the short-run (generally less than or equal to 2-3 years) but more persistent in countries with more rigid labor market institutions. The effects are larger for youth unemployment. It is often found that unemployment for youth is more sensitive to labor market institutions. Nickell and Layard (1999) argue that minimum wages are likely to have a significant impact on the unemployment rate of low skill and young workers.

In terms of theoretical work, Prescott (2004) uses a neoclassical growth model with a stand-in household to argue that variations in tax rates account for most differences in labor supply in advanced G7 economies. Ohanian, Raffo and Rogerson (2008), also exploiting a neoclassical growth model, confirm that taxes can account for a large proportion of cross-country differences and variation in hours worked (the product of total civilian employment and annual hours per worker) for a set of OECD countries. Ljungqvist and Sargent (2007) examine the previous analysis and emphasize the role of differences in unemployment benefits rather than tax rates to explain cross-country differences in employment.[10]

3.4 Baseline Environment

In this section we describe the theoretical framework without permanent heterogeneous ability to avoid cumbersome notation[11]. The framework consists of a life-cycle model with on-the-job human capital accumulation. There are frictional labor markets with search and matching. Search is directed and markets are labeled by age of the worker, human capital and the first period payment to the worker. After the first period, wages are determined through a Nash-bargaining process. There are aggregate and idiosyncratic (match-specific) productivity shocks.

3.4.1 Demographics

- There is continuum of workers of measure normalized to one, uniformly distributed across overlapping generations with age $t \in \{1, ..., T\}$. Each worker is endowed with one indivisible unit of labor.

[10]The role of segmented/two-tier labor markets has also been analyzed, see Blanchard and Landier (2002) and Cahuc and Postel-Vinay (2002).

[11]Introducing this dimension is straightforward, as it amounts to solving for the block recursive equilibrium for the different types of ex-ante heterogeneous workers. With that extension markets are also indexed by ability of the worker.

- The mass of entering (newly born) workers is equal to $1/T$ which equals the mass of retiring/dying workers.

- There is a continuum of firms with positive measure (continuum of potential firms having infinite mass).

3.4.2 Preferences and Technology

- We assume risk neutrality for both workers and firms and a common discount factor $\beta \in (0, 1)$.

- Stochastic shocks: aggregate productivity is denoted $y \in Y$ with AR(1) process $\Lambda(y' \mid y)$ and match idiosyncratic productivity $z \in Z$ with AR(1) process denoted $\Lambda(z' \mid z)$, we may also write $s = (z, y)$ and $\Lambda(s' \mid s)$ as the joint process (this allows for more general joint stochastic processes).

- The human capital of the worker is $h \in \mathbf{R}_+$, which evolves according to the law of motion $h' = h + 1$ for the periods during which the worker is employed and remains fixed when the worker is not employed. There is an initial level of human capital $\underline{h}$ for all newborn workers. When a match between a worker and a firm is destroyed, human capital depreciates to $\mu(h)$, with lower bound at $\underline{h}$. The upper bound on human capital is $\overline{h}$, with $\overline{h} \leq T$.

- Production is carried out in a match between a firm and a worker with production technology $f(y, z, h)$.

3.4.3 Markets

- There is continuum of markets labeled by $(w, h, t, y) \in \mathbf{R}_+ \times \mathbf{N}^3$ where firms commit to pay w for the first period of the match to a worker with (h, t).

- After the initial period the wage is determined through Nash-bargaining when the worker has no alternative job offer. We assume the worker accepts an offer in the market he has chosen to search[12].

- The measure of unemployed workers is written as $u(h,t)$ where $u : \mathbf{N}^2 \to \mathbf{R}_+$, the measure of employed workers is $e(z,h,t)$ where $e : Z \times \mathbf{N}^2 \to \mathbf{R}_+$. The aggregate state vector is then $\psi = (u, e, y)$.

- The tightness for a labor market with (w,h,t) is denoted $\theta_t(w,h,\psi)$.

3.4.4 Timing

For the rest of this section we assume that a *block recursive equilibrium* exists and omit ψ from the vector of state variables, the aggregate shock y does remain as a relevant aggregate state variable. The existence of the *block recursive equilibrium* is proven by construction in the appendix, following the methodology of Menzio et al. (2012) for a life cycle economy with directed search and free-entry of firms (adapted to introduce our extensions). The timing within a period is as follows:

- **Entry-and-Exit of Workers, Aggregate Shock.** At the beginning of the period newly born workers enter the market and workers of age $T+1$ retire and die. The aggregate productivity shock y is revealed.

- **Search and Matching.** The unemployed workers search for a job with probability λ_u, while employed workers are allowed to search for an alternative job with probability λ_e. A firm opens a vacancy after paying vacancy cost c_v. A worker in market (w,h,t,y) meets a vacancy with probability $p(\theta_t(w,h,y))$ where $p : \mathbf{R}_+ \to [0,1]$ is a twice-differentiable, strictly increasing and strictly concave function with $p(0) = 0$ and $p(\infty)$=1. A vacancy in market (w,h,t,y) meets a worker with probability $q(\theta_t(w,h,y))$ where $q : \mathbf{R}_+ \to [0,1]$ is a twice-differentiable, strictly decreasing function and with $q(\theta) = p(\theta)/\theta$, $q(0) = 1$ and

[12] At the bargaining stage the idiosyncratic productivity level available for production for a potential new match is known but not the value that will be effective for production at the existing match in that same period.

$q(\infty)$=0.

- **Wage Determination.** When the worker meets a new firm, the firm pays the initial posted w in the first period. If the worker is matched with no alternative job offers, the wage is determined through Nash-bargaining with the current firm. If no agreement is reached, the match is destroyed. The unemployed worker accepts the offer he receives (if any), otherwise produces and consumes b.

- **Production.** The idiosyncratic productivity state at the beginning of the period is z, at the production stage the new idiosyncratic shock z' is revealed (for new matches it is known in advance[13] and equal to $\overline{z}$). The match produces $f(y, z', h)$. The accumulation of human capital takes place with production: a matched worker that enters the period and produces with human capital h, is endowed with human capital $h' = h + 1$ immediately after production takes place. The matched worker gets paid and his consumption takes place.

- **Exogenous Separation.** There is a probability δ of a shock that destroys the match (exogenous job destruction).

3.4.5 Value of the Worker

Let's consider in parts the problem of the unemployed worker before the search stage. With probability λ_u the unemployed individual has the possibility of searching, if successful receives wage w^u and enters next period as an employed worker with probability $1 - \delta$. This part of the value of the unemployed worker is given by:

$$\lambda_u\, p(\theta_t(w^u, h, y)) \left\{ w^u + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y) \left((1-\delta)\, V_{t+1}(h', \overline{z}, y') + \delta\, U_{t+1}(\mu(h'), y') \right) \right\}$$

All new matches produce with idiosyncratic productivity value $\overline{z}$ in their first period of existence, it will also be the state value at the beginning of the following period.

[13]We may set $\overline{z}$ equal to any value $z \in Z$.

The unemployed worker may remain unemployed for two reasons: he was not given a chance to search for a job, or was unsuccessful in his search. In this case, he produces and consumes b today and enters the next period with unemployment status, with unchanged level of human capital at age $t+1$. This component can be written as:

$$(1-\lambda_u\, p(\,\cdot\,))\,\left\{ b+\beta \sum_{\{y'\}} \Lambda(y'\,|\,y)\, U_{t+1}(h,y') \right\}$$

We can write the beginning-of-the-period value of unemployment as:

$$U_t(h,y) = \max_{\{w^u\}} b+\beta \sum_{\{y'\}} \Lambda(y'\,|\,y) \Big\{ U_{t+1}(h,y') + \lambda_u\, p(\theta_t(w^u,h,y))\, S^u_t(w^u,h,y') \Big\}$$

where $S^u_t(w^u,h,y')$ summarizes the gain for the worker of finding a match:

$$S^u_t(w^u,h,y') = \left[\frac{w^u-b}{\beta} + (1-\delta)\, V_{t+1}(h',\overline{z},y') + \delta\, U_{t+1}(\mu(h'),y') - U_{t+1}(h,y') \right]$$

V_{t+1} is the beginning of the period value of the matched worker (after the aggregate shock is revealed). The policy function of the unemployed worker is $w^u_t(h,y)$.

A matched worker may be given a chance to search for an alternative job offer with probability λ_e, if successful he receives the posted wage of the corresponding labor market and enters the next period as a matched worker with probability $1-\delta$, this possibility can be written as:

$$\lambda_e\, p(\theta_t(w^a,h,y)) \left\{ w^a + \beta \sum_{\{y'\}} \Lambda(y'\,|\,y)\, \big((1-\delta)\, V_{t+1}(h',\overline{z},y') + \delta\, U_{t+1}(\mu(h'),y') \big) \right\}$$

If the currently matched worker does not receive an alternative job offer:

$$(1-\lambda_e\, p(\,\cdot\,))\, V^b_t(h,z,y)$$

where the wage in $V_t^b(h,z,y)$ is determined through Nash-bargaining. The value function is then:

$$\begin{aligned} V_t(h,z,y) =& \lambda_e\, p(\,\cdot\,) \Bigg\{ w^a + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y) \left((1-\delta)\, V_{t+1}(h', \overline{z}, y') + \delta\, U_{t+1}(\mu(h'), y') \right) \Bigg\} \\ & + (1 - \lambda_e\, p(\,\cdot\,))\, V_t^b(h,z,y) \end{aligned}$$

The policy function for a matched worker is denoted $w_t^a(h,z,y)$. Before discussing how this value is determined through the bargaining process it will be useful to describe the problem of the firm.

3.4.6 Value of the Firm

At the beginning of the period, when the aggregate shock is revealed, the value of a currently matched firm is $F_t(h,z,y)$. After the search stage there are two possible situations, with probability $\lambda_e\, p(\theta_t(w^a,h,y))$ the worker has found an alternative job offer and the previous match is destroyed. If the worker has no alternative job offer the new value of the firm is determined at the bargaining stage $F_t^b(h,z,y)$. We can then write the beginning-of-the-period value of the firm as:

$$F_t(h,z,y) = (1 - \lambda_e\, p(\theta_t(w^a,h,y)))\, F_t^b(h,z,y)$$

The value of a newly matched firm is $G_t(w^a,h,\overline{z},y)$:

$$G_t(w^a,h,\overline{z},y) = f(y,\overline{z},h) - w^a + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)\, F_{t+1}(h', \overline{z}, y'),$$

We turn next to the bargaining stage.

3.4.7 Determination of Wages

If the worker was unsuccessful in obtaining an alternative offer (whether because he did not have the possibility of searching, or was not successful in the search stage), his outside option is (human capital depreciates if the match is destroyed):

$$b + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)\, U_{t+1}(\mu(h), y')$$

while reaching an agreement with the current employer gives (before z' is revealed):

$$w^b + \beta \sum_{\{s'\}} \Lambda(s' \,|\, s) \Big\{ (1-\delta)\, V_{t+1}(h', z', y') + \delta\, U_{t+1}(\mu(h'), y') \Big\}$$

For the firm, at the bargaining stage the outside value is zero. The value of maintaining the match is:

$$F_t^b(h, z, y) = -w^b + \sum_{\{s'\}} \Lambda(s' \,|\, s) \Big\{ f(y, z', h) + \beta\,(1-\delta) F_{t+1}(h', z', y') \Big\}$$

Note that current period production takes place with productivity value z' and y. There is a cutoff function $z_t^b(h, y)$, the lowest level of the idiosyncratic productivity shock such that the joint surplus of the match is non-negative. Given these values, worker and firm bargain over the wage, through a Nash-bargaining process where the worker has bargaining power ξ (see Appendix). Finally $F_{T+1} = 0$, $U_{T+1} = 0$ and $V_{T+1} = 0$.

3.4.8 New Vacancies and Free Entry Condition

To close the model we specify the free entry condition of firms. The cost of a vacancy is c_v, in equilibrium the following condition has to hold:

$$c_v \geq q(\theta_t(w, h, y)) \left\{ f(y, \overline{z}, h) - w + \beta\,(1-\delta) \sum_{\{y'\}} \Lambda(y' \,|\, y)\, F_{t+1}(h', z, y') \right\}$$

and $\theta_t(w,h,y) \geq 0$ with complementary slackness.

3.5 Block Recursive Equilibrium

Definition. A *Block Recursive Equilibrium* (BRE) consists of value functions U_t for unemployed workers, V_t for employed workers, F_t for previously matched firms and G_t for newly matched firms, policy functions w_t^u for unemployed workers and w_t^a for employed workers, a bargained wage function w_t^b determined between an employed worker and a firm, a cutoff productivity function z_t^b, and a tightness function θ_t for $t = 1, ..., T$ such that (i) U_t, V_t, F_t, G_t, w_t^u, w_t^a, w_t^b, z_t^b and θ_t depend on ψ only through y for $t = 1, ..., T$, (ii) F_t, G_t and θ_t are consistent with the firm's rationality and the free-entry condition for $t = 1, ..., T$, (iii) U_t and w_t^u solve the unemployed worker's problem for $t = 1, ..., T$, (iv) V_t and w_t^a solve the employed worker's problem for $t = 1, ..., T$, and (v) w_t^b and z_t^b solve the bargaining problem between an employed worker and a firm for $t = 1, ..., T$.

Theorem. A recursive equilibrium exists and is block recursive and unique.

The proof is in the appendix for the case without human capital depreciation (the extension is straightforward). To gain some intuition on this result first consider the assumption of directed search. Markets are indexed by age and human capital of the worker (and ability when this extension is considered). Thus, a firm opening a vacancy in a particular market will know the characteristics of the worker that it will potentially find. If search was not directed, to calculate the expected discounted profits of opening a vacancy the firm would need to know the distribution of workers with different characteristics (for example, human capital determines in part the productivity of the match).

In the market that the workers searches for a job the number of vacancies will adjust so that the free-entry condition holds for the firms. There are different pairs of first-period wages and market tightness that could deliver zero expected discounted profits for firms. The additional condition that determines this pair in equilibrium is a concave maximization search problem for each particular type of worker. In the last period of the worker, it is straightforward to verify that all value and policy functions as well as bargained wages are independent of the distribution of workers over their individual state variables. By backward induction a *block recursive equilibrium* can be constructed.

3.6 Quantitative Analysis

In this section we describe the specification employed for the different functions of the model, the calibration strategies and standard parameters employed in the literature. We then simulate the economy to evaluate the role of the tax-wedge on unemployment rates.

3.6.1 Baseline Parameters and Function Specifications

We modify the production function of Menzio et al. (2012), by considering an AR(1) process for idiosyncratic productivity shocks, AR(1) process for aggregate productivity, heterogeneous ability of workers. The production function is:

$$f(a, y, z, h) = a\, e^{z+y}\, h^{\gamma}$$

where a is the permanent ability of the individual, z is the match-idiosyncratic productivity shock, y is the aggregate productivity shock, γ determines curvature with respect to human capital in the production function.

- A time period is one month and $\beta \in [0.996, 0.9967]$ is typically calibrated so that the annual real interest rate is equal to 4-5 percent.
- Bargaining power is equal for firms and workers, $\xi = 1/2$.
- We set the home production parameter b to target a total average unemployment rate of 6.5 percent. The vacancy cost is set to 10.42 times the value of home

production following Menzio et al. (2012).

- In the case with no initial heterogeneity $a = 1$, with heterogeneity $a \in \{0.9, 1.0, 1.1\}$ with weights $\{0.25, 0.50, 0.25\}$, respectively. The range of human capital is from $\underline{h} = 1$ to $\overline{h}$ (set to match the peak of mean earnings, Huggett et al., 2006). The function for human capital depreciation is the grid approximation to $\mu(h) = h/(1.08)$.

Table 3.3: Parameters

parameter description	**par.**	**value**
discount factor	β	0.996
periods of life	T	40×12
vacancy cost	c_v	$10.42 \times b$
production - curvature	γ	0.06
human capital range	$\overline{h}$	25×12
human capital depreciation	$\mu(h)$	$h/(1.08)$
exogenous destruction	δ	0.01
unemployed search prob.	λ_u	1.00
on-the-job search prob.	λ_e	0.80
matching function	$p(\theta)$	$min\{\theta^{1/2}, 1\}$
aggregate process autocorrelation	ρ_y	0.90
aggregate process volatility	σ_y	0.01
idiosyncratic process autocorrelation	ρ_z	0.00
idiosyncratic process volatility	σ_z	0.12
bargaining parameter	ξ	1/2

Parameters related to probabilities and distributions:

- For the aggregate productivity process $\Lambda(y' \mid y)$, considering a quarterly time period, Den Haan et al. (2000) utilize an autocorrelation[14] of 0.95 and standard deviation 0.007. Pries (2008), in a monthly model, selects the autocorrelation

[14]We apply the Rouwenhorst method of approximating a stationary AR(1) process following Kopecky and Suen (2010), this method is found to be reliable relative to other methods in approximating highly persistent processes.

and the standard deviation process to target quarterly US data on real average output per worker in the non-farm business sector, with autocorrelation of 0.878 and standard deviation of 0.02.

- For the idiosyncratic productivity process, Den Haan et al. (2000) consider an iid shock with standard deviation equal to 0.101. Bils et al. (2011) consider a persistence of idiosyncratic productivity of 0.97 and a standard deviation of 0.13. The initial idiosyncratic productivity level for new matches is set to the highest idiosyncratic productivity level.

- For long-term employment relationships, quarterly US worker separation rates lie in the range 8-10 percent (Den Haan et al , 2000; pg. 490). Den Haan et al. (2000) consider a 10 percent rate of total separation (see also Pries, 2008), with an exogenous separation rate of 0.068. We consider exogenous job destruction and the possibility of endogenous job destruction. In Menzio and Shi (2011) the exogenous destruction rate is $\delta \in \{0.012, 0.026\}$.

- λ_e determines the rate of transition to new jobs, λ_u governs the rate of transition from unemployment to employment. In Menzio and Shi (2011) $\lambda_e \in \{0.735, 0.904\}$.

3.6.2 Business Cycle Simulations

We conduct simulations to learn about the impact of the tax-wedge and the role of heterogeneity in the ability of workers. The benchmark tax wedge is 0.344.[15] In the case of no heterogeneity, for example, increasing the tax wedge by 5 p.p. increases the unemployment rate from 0.065 to 0.079.

[15]The OECD definition of the total tax wedge: combined central and sub-central government income tax plus employee and employer social security contribution taxes, as a percentage of labour costs defined as gross wage earnings plus employer social security contributions. For the US the total tax wedge is 34.4%.

Table 3.4: Business Cycle Simulations: No Heterogeneity

average	$\tau = 0.344$	$\tau = 0.394$	$\tau = 0.444$
youth unemployment	0.094	0.114	0.164
prime unemployment	0.059	0.071	0.102
total unemployment	0.065	0.079	0.115
volatility	$\tau = 0.344$	$\tau = 0.394$	$\tau = 0.444$
youth unemployment	0.037	0.039	0.039
prime unemployment	0.036	0.048	0.058
total unemployment	0.026	0.041	0.050

The unemployment rate for workers of age 21-25 is always higher[16] compared to the unemployment rate for those aged 35-45 and the total unemployment rate. The tax wedge increases the volatility of unemployment rates in the case of no heterogeneity, but the effect is not monotonic in a version of the model with ex-ante heterogeneity.[17]

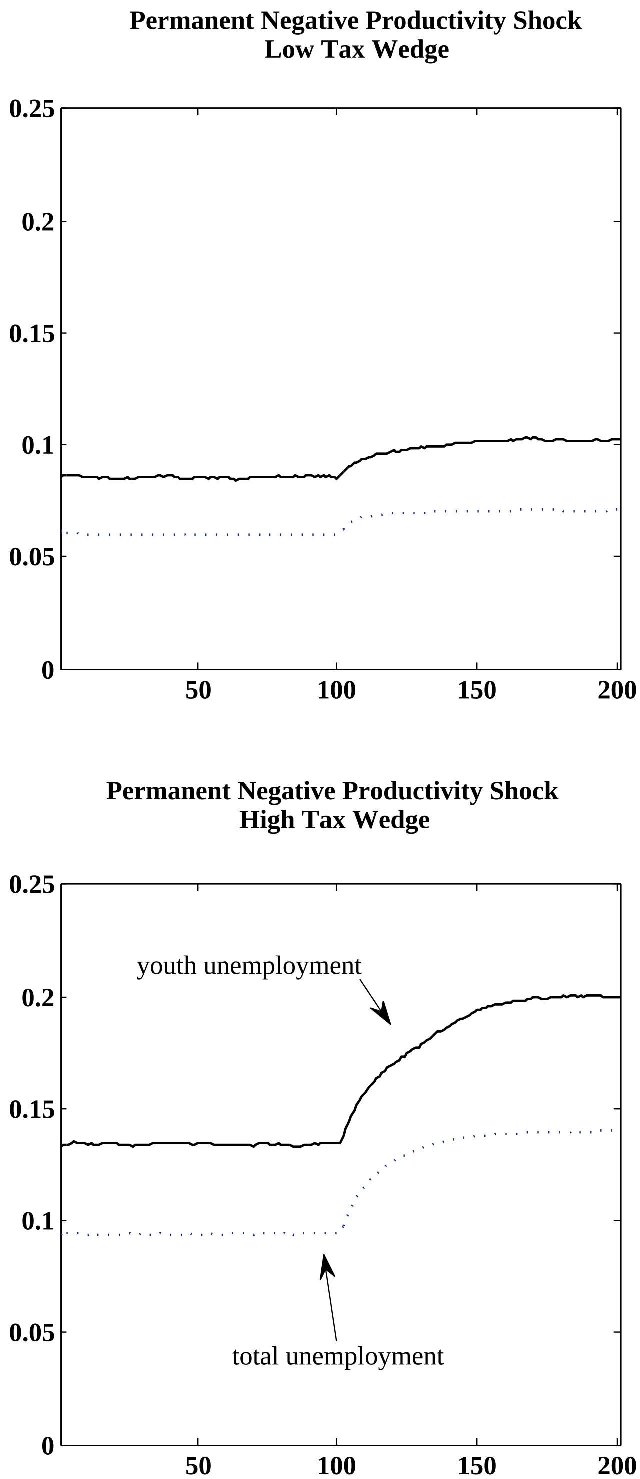
Table 3.5: Business Cycle Simulations: With Heterogeneity

average	$\tau = 0.344$	$\tau = 0.394$	$\tau = 0.444$
youth unemployment	0.093	0.118	0.343
prime unemployment	0.058	0.073	0.294
total unemployment	0.065	0.082	0.305
volatility	$\tau = 0.344$	$\tau = 0.394$	$\tau = 0.444$
youth unemployment	0.039	0.046	0.016
prime unemployment	0.042	0.052	0.011
total unemployment	0.032	0.045	0.010

[16] Individuals enter the market unemployed at age 20, we give them one year to find a job (12 *opportunities*) and consider age 21-25 for youth unemployment.

[17] For the computation of volatility, we first take the natural log of the series, then remove the Hodrick-Prescott trend with a filter parameter of 10^5 (see Pries, 2005).

Figure 3.1: Simulation of a Recession



3.6.3 Simulations of a Recession

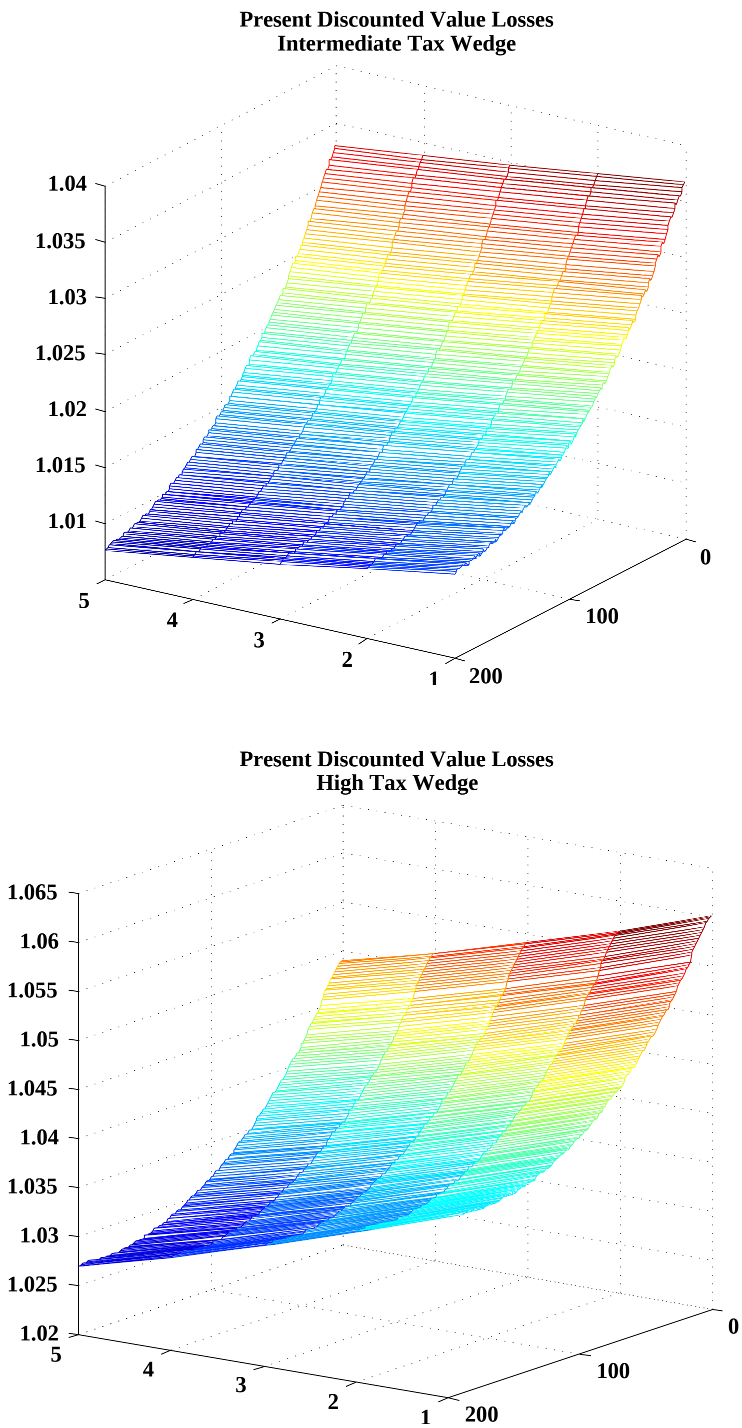
In this section we simulate two economies, one with a tax wedge of 0.344 and another economy with a tax wedge 10 percentage points higher, equal to 0.444. In both economies the aggregate productivity shock permanently falls from the highest to lowest possible state. In the high tax-wedge economy, the starting difference between youth and total unemployment is larger compared to the low tax-wedge economy and is more amplified by a recession.

3.6.4 Losses due to Unemployment in Present Discounted Values

In this final quantitative section we compute the expected present discounted losses in labor earnings caused by unemployment. The graphs below show the ratio of the expected present discounted value of labor earnings of an employed worker of a particular age (in months starting at 20 years old), relative to the expected present discounted value of labor earnings for an individual of the same age that lost his job and whose human capital depreciated accordingly.[18] The graphs show this ratio for different ages and in 5 different states of the aggregate productivity (5 is the highest aggregate productivity and 1 is the lowest). The main results are that losses are bigger: (1) in worse aggregate states of the economy, (2) for younger individuals, (3) in the economy with the higher tax wedge. Additionally, in a version of the model with ex-ante heterogeneity, the losses are larger for low ability individuals.

[18]See the appendix for a mathematical derivation of the expected present discounted value of labor earnings.

Figure 3.2: Losses due to Unemployment



3.7 Final Comments

Recessions generate sizable losses for young workers entering the labor force. Unemployment generates a direct income loss but also a fall in future income attributed to foregone human capital accumulation. We analyze a life-cycle model of workers with heterogeneous ability and on-the-job human capital accumulation and depreciation due to job loss[19]. We find that unemployment rates of young workers are typically higher and more sensitive to the tax-wedge, consistent with the empirical estimates. Long-term earnings losses generated by match destruction are bigger: (1) in worse aggregate states of the economy, (2) for younger individuals, (3) in the economy with the higher tax wedge, (4) for ex-ante low ability individuals.

[19]This depreciation may be due to firm-specific or occupation-specific human capital. Kambourov and Manovskii (2009) find that when occupational experience is taken into account, tenure in a certain industry or a particular employer has quantitatively little importance in accounting for wages. This evidence could be interpreted as contrary to information theories of wage formation where employer learn about the productivity of their workers. Occupation specific human capital is transferable across employers.

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Appendices

Appendix A

Appendix to Chapter 2

A.1 Stable Matching Equilibrium

A.1.1 Gale and Shapley Algorithm

After women and men enter the marriage market, their marital status is determined in a stable pair of matchings (μ_S, μ_M). Here, we describe how to compute such a pair of matchings by applying the Gale and Shapley (1962) algorithm. As we have said, we are going to focus on a M-optimal stable matching equilibrium. But, with a small change, the method can be also applied for a W-optimal equilibrium. To begin with, we have the following lemma, which is easily derived from the participation constraints of marriage problem.

Lemma A.1. $\forall i \in \mathcal{I}^f, \forall j \in \mathcal{I}^m$,

$$
\begin{aligned}
& \hat{V}^f_M(h^f_i, a^f_i, h^m_j, a^m_j, \gamma) \geq \hat{V}^f_S(h^f_i, a^f_i, h^m_j, a^m_j, \gamma), \\
\iff & \\
& \hat{V}^m_M(h^f_i, a^f_i, h^m_j, a^m_j, \gamma) \geq \hat{V}^m_S(h^f_i, a^f_i, h^m_j, a^m_j, \gamma).
\end{aligned}
$$

Now we consider the situation in which each male proposes to a female in a given round, say the n-th round. Let $\lambda(j) = 1$ if a type-j male is tentatively matched with a partner from the previous round, and $\lambda(j) = 0$ if he is not matched at the beginning of the n-th round.

1. In the n-th round, if $\lambda(j) = 0$, then a type-j male proposes to a type-i female with a relationship $R \in \{S, M\}$, who gives him the highest utility value $\hat{V}_R^m(h_i^f, a_i^f, h_j^m, a_j^m, \gamma)$ among the females who have never received his proposal ($\rho(i, j) = 0$).

2. Each woman accepts the proposal which gives her the highest $\hat{V}_R^f(h_i^f, a_i^f, h_j^m, a_j^m, \gamma)$ among the proposals which she received in the n-th round plus the one she carried over from the previous round. The selected male changes his status to $\lambda(j) = 1$. All other rejected males (these might include her partner from the previous round) change their status to $\lambda(j) = 1$. All the males $j' \in \mathcal{I}^m$ who newly proposed to her change their status to $\rho(i, j) = 1$.

3. Go back to step 1 until $\forall j \in \mathcal{I}^m, \lambda(j) = 1$.

Here unlike in the original Gale and Shapley algorithm, men choose a type of relationship (marriage or a non-marital relationship) every time they make an offer. Also, Lemma A.1 assures that a woman doesn't have incentives to reject the highest offer she receives.[1]

A.1.2 Proof of Theorem 3

Proof. We will show that a pair of matchings (μ_S, μ_M) obtained through the above algorithm always satisfies the two conditions in Definition 2. Since condition 1 holds obviously, we will only check whether the condition 2 holds or not. Suppose, to the contrary, that within the matchings (μ_S, μ_M), there exist a pair of couples $(i, \mu_R(i))$,$(\mu_{R'}(j), j)$,

[1] If Lemma A.1 doesn't hold, then, women might have strategic motives to reject the offer which gives her the highest utility value among those she receives in the current round.

and relationships $R, R', R'' \in \{S, M\}$ such that

$$\hat{V}^f_{R''}\left(h^f_i, a^f_i, h^m_j, a^m_j, \gamma\right) > \hat{V}^f_R\left(h^f_i, a^f_i, h^m_{\mu_R(i)}, a^m_{\mu_R(i)}, \gamma\right),$$
$$\hat{V}^m_{R''}\left(h^f_i, a^f_i, h^m_j, a^m_j, \gamma\right) > \hat{V}^m_{R'}\left(h^f_{\mu_{R'}(j)}, a^f_{\mu_{R'}(j)}, h^m_j, a^m_j, \gamma\right).$$

Then one of the following two must be true: (1) type-j male didn't propose to a type-i female when she gave the highest utility value among available mates, or (2) a type-i female didn't accept a type-j male's offer when he gave her the highest utility value among the offers she received. Both of these contradict the algorithm described above.

□

A.1.3 Proof of Theorem 6

Proof. We will show that a pair of matchings (μ_S, μ_M) obtained through the above algorithm is the unique M-optimal pair. In particular, we will prove that in the above algorithm, no man is ever rejected by an achievable woman. Consequently, the stable pair of matchings (μ_S, μ_M) that is produced in the above algorithm matches each man to his most preferred achievable woman, and is, therefore, the unique M-optimal stable pair of matchings. This proof is based on the work of Roth and Sotomayor (1990).

The proof is by induction. Assume that up to a given step in the procedure no man has yet been rejected by a woman who is achievable for him. At this step, suppose woman i rejects man j. If she rejects j in favor of man j', whom she keeps engaged, then she prefers j' to j. Then we must show that i is not achievable for j.

We know j' prefers i to any women except for those who have previously rejected him and hence (by inductive assumption) are unachievable for him. Consider a hypothetical pair of matchings (μ'_S, μ'_M) that matches j to i and everyone else to an achievable partner. Then j' prefers i to his partner at (μ'_S, μ'_M). So, the pair (μ'_S, μ'_M) is unstable, since it is blocked by j' and i, who each prefer the other to their partner at (μ'_S, μ'_M).

Therefore, there is no stable matching that matches i and j, and so they are unachievable for each other, which completes the proof.

$\square$

A.2 Robustness of First-Stage Estimatation

Table A.1: First Stage Regressions: Total Fertility Rate for Non-Marital and Marital Births with the 5-Years Moving Average of the CSE Measures

Dependent Variable	Non-Marital Total Fertility Rate			Marital Total Fertility Rate		
CSE Measures (5-Year Moving Average)						
1) Collection	-0.46814**			0.39790**		
	(0.09619)			(0.10756)		
2) Expenditure		-0.01813**			0.01962**	
		(0.00345)			(0.00383)	
3) Paternity			-0.08773**			0.03272
			(0.02273)			(0.02242)
Average Wage	-0.01403**	-0.01301**	-0.01501**	-0.00663	-0.00713	-0.00724
	(0.00419)	(0.00415)	(0.00466)	(0.00468)	(0.00462)	(0.00460)
Unemp. Rate	0.00633**	0.00578**	0.00863**	-0.00391**	-0.00354*	-0.00165
	(0.00132)	(0.00130)	(0.00184)	(0.00147)	(0.00145)	(0.00181)
Gender Gap	-0.01025	-0.00844	-0.01077	0.00521	0.00387	0.00657
	(0.01423)	(0.01418)	(0.01483)	(0.01591)	(0.01577)	(0.01463)
Frac. Black	-0.54892**	-0.56211**	-0.44155**	0.01986	0.03852	-0.01728
	(0.11791)	(0.11771)	(0.13617)	(0.13185)	(0.13088)	(0.13433)
Frac. Hisp.	0.27465	0.23108	0.33257†	-0.55493**	-0.53392**	-0.23748
	(0.17962)	(0.17815)	(0.19925)	(0.20085)	(0.19809)	(0.19655)
Frac. HS DP	0.13233	0.12098	0.09186**	0.14240	0.15326	0.18223
	(0.10080)	(0.10054)	(0.11732)	(0.11271)	(0.11179)	(0.11574)
Max AFDC	0.06693**	0.06504**	0.09186**	0.06043**	0.06288**	0.07658**
	(0.00496)	(0.00499)	(0.00623)	(0.00555)	(0.00554)	(0.00615)
Intercept	-62.26066**	-58.74095**	-54.16074**	17.10579**	14.79859**	11.26589†
	(5.22574)	(5.07200)	(6.52845)	(5.84324)	(5.63974)	(6.44007)
State-Specific						
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Trends	Yes	Yes	Yes	Yes	Yes	Yes
N	857	857	705	857	857	705
R^2	0.96154	0.96174	0.95876	0.97529	0.97135	0.97720
F	171.33623	172.25725	126.92143	270.51605	248.18175	233.96588

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

(Standard errors are in parenthesis.)

Table A.2: Marriage Rate Regression without State-Specific Time Trends.

Dependent Variable	Marriage Rate		
CSE Measures (5-Year Moving Average)			
1) Collection	0.02396**		
	(0.00525)		
2) Expenditure		0.00112**	
		(0.00020)	
3) Paternity			0.00190†
			(0.00101)
Average Wage	-0.00017	-0.00027	-0.00034
	(0.00024)	(0.00024)	(0.00021)
Unemp. Rate	-0.00046**	-0.00043**	-0.00049**
	(0.00006)	(0.00006)	(0.00007)
Gender Gap	-0.00168	-0.00117	0.00142
	(0.00229)	(0.00226)	(0.00200)
Frac. Black	0.00816	0.00813	-0.00372
	(0.00609)	(0.00603)	(0.00552)
Frac. Hisp.	-0.02013	-0.01856	-0.00783
	(0.01341)	(0.01327)	(0.01181)
Frac. HS DP	0.00443	0.00425	0.00519
	(0.00502)	(0.00496)	(0.00458)
Max AFDC	-0.00047†	-0.00036	0.00018
	(0.00025)	(0.00025)	(0.00027)
Intercept	2.34269**	2.20281**	1.96177**
	(0.26385)	(0.25569)	(0.26319)
State-Specific			
Fixed Effects	Yes	Yes	Yes
Specific Trends	Yes	Yes	Yes
N	634	634	506
R^2	0.96874	0.96933	0.98172
F	179.96616	183.53104	237.96394
Significance levels :	† : 10%	∗ : 5%	∗∗ : 1%

(Standard errors are in parenthesis.)

Table A.3: First Stage Regressions: Total Fertility Rate for Non-Marital and Marital Births without State-Specific Time Trends.

Dependent Variable	Non-Marital Total Fertility Rate			Marital Total Fertility Rate		
CSE Measures (3-Year Moving Average)						
1) Collection	-0.27859**			-0.21389*		
	(0.05941)			(0.09147)		
2) Expenditure		-0.01735**			-0.01440**	
		(0.00218)			(0.00341)	
3) Paternity			-0.03714**			-0.07411**
			(0.01239)			(0.01682)
Average Wage	-0.00714†	-0.00756*	-0.00795*	0.02292**	0.02241**	0.02541**
	(0.00367)	(0.00356)	(0.00391)	(0.00565)	(0.00558)	(0.00531)
Unemp. Rate	0.00132	0.00216†	0.00013	-0.00399*	-0.00330†	-0.00207
	(0.00128)	(0.00125)	(0.00135)	(0.00197)	(0.00196)	(0.00183)
Gender Gap	0.01130	0.01111	-0.00189	-0.03819	-0.03859	-0.05314*
	(0.01651)	(0.01612)	(0.01635)	(0.02542)	(0.02522)	(0.02221)
Frac. Black	-0.53101**	-0.56611**	-0.46910**	0.17598	0.14454	0.25145
	(0.11912)	(0.11648)	(0.12910)	(0.18341)	(0.18224)	(0.17534)
Frac. Hisp.	0.45978**	0.46487**	0.90602**	0.96065**	0.95865**	0.84388**
	(0.13544)	(0.13121)	(0.15132)	(0.20853)	(0.20530)	(0.20552)
Frac. HS DP	0.25737**	0.25041**	0.07038	-0.49354**	-0.49574**	-0.52108**
	(0.09159)	(0.08890)	(0.09845)	(0.14101)	(0.13909)	(0.13371)
Max AFDC	0.03307**	0.03569**	0.05378**	0.02653**	0.02868**	0.04181**
	(0.00357)	(0.00350)	(0.00501)	(0.00549)	(0.00547)	(0.00680)
Intercept	-62.40616**	-62.74655**	-55.96561**	39.13232**	38.45340**	38.05713**
	(2.55343)	(2.27437)	(2.37166)	(3.93135)	(3.55851)	(3.22118)
State-Specific						
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Trends	No	No	No	No	No	No
Aggregate						
Trends	Yes	Yes	Yes	Yes	Yes	Yes
N	908	908	806	908	908	806
R^2	0.93801	0.94084	0.93834	0.92703	0.92807	0.93968
F	174.02847	228.5594	192.40494	182.59391	185.45679	196.96413

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

(Standard errors are in parenthesis.)

Table A.4: Marriage Rate Regression without State-Specific Time Trends.

Dependent Variable	Marriage Rate		
CSE Measures (3-Year Moving Average)			
1) Collection	-0.00957*		
	(0.00411)		
2) Expenditure		0.00014	
		(0.00017)	
3) Paternity			-0.00087
			(0.00077)
Average Wage	-0.00042†	-0.00027	-0.00038†
	(0.00024)	(0.00024)	(0.00023)
Unemp. Rate	-0.00035**	-0.00036**	-0.00028**
	(0.00008)	(0.00008)	(0.00007)
Gender Gap	0.00036	0.00049	0.00043
	(0.00324)	(0.00327)	(0.00307)
Frac. Black	-0.01253†	-0.01222	-0.01592*
	(0.00581)	(0.00762)	(0.00754)
Frac. Hisp.	-0.01693	-0.01203	-0.01354
	(0.01112)	(0.01112)	(0.01116)
Frac. HS DP	-0.01542*	-0.01594**	-0.00984†
	(0.00599)	(0.00601)	(0.00581)
Max AFDC	0.00002	-0.00004	0.00072*
	(0.00022)	(0.00023)	(0.00030)
Intercept	1.09778**	1.34034**	1.05778**
	(0.17297)	(0.15891)	(0.15130)
State-Specific			
Fixed Effects	Yes	Yes	Yes
Trends	No	No	No
Aggregate			
Trend	Yes	Yes	Yes
N	681	681	591
R^2	0.91392	0.91327	0.93437
F	120.64919	119.65849	150.47517

Significance levels : † : 10% $*$: 5% $**$: 1%

(Standard errors are in parenthesis.)

A.3 Calibration for Intergenerational Analysis

This appendix lists the result of the calibration for intergenerational analysis. The followings are the estimated value of the parameters, and the values for the targets.

Table A.5: Estimated Parameters for Intergenerational Exercise

Name	Parameter	Estimates
Parameter for Conditional Mean	ϵ_1	3.385
Parameter for Conditional Mean	ϵ_2	0.856
Parameter for Gender Gap	μ_g	2.896
Parameter for Conditional Variance	σ_g	0.125

Table A.6: The Match Between the Model and the Data for Intergenerational Exercise

Name		Data	Model
Log Mean of Human Capital for Women	μ_h^f	2.200	2.217
Log Mean of Human Capital for Men	μ_h^m	2.580	2.555
Log Variance of Human Capital for Women	σ_h^f	0.755	0.801
Log Variance of Human Capital for Men	σ_h^m	0.755	0.721
Intergenerational Correlation of Income	ρ_g	0.730	0.711

Appendix B

Appendix to Chapter 3

B.1 Block Recursive Equilibrium

This appendix proves the existence and uniqueness of the *Block Recursive Equilibrium* for an economy without human capital depreciation (this extension is straightforward).

Definition. A *Block Recursive Equilibrium* (BRE) consists of value functions U_t for unemployed workers, V_t for employed workers, F_t for previously matched firms and G_t for newly matched firms, policy functions w_t^u for unemployed workers and w_t^a for employed workers, a bargained wage function w_t^b determined between an employed worker and a firm, a cutoff productivity function z_t^b, and a tightness function θ_t for $t = 1, ..., T$ such that (i) U_t, V_t, F_t, G_t, w_t^u, w_t^a, w_t^b, z_t^b and θ_t depend on ψ only through y for $t = 1, ..., T$, (ii) F_t, G_t and θ_t are consistent with the firm's rationality and the free-entry condition for $t = 1, ..., T$, (iii) U_t and w_t^u solve the unemployed worker's problem for $t = 1, ..., T$, (iv) V_t and w_t^a solve the employed worker's problem for $t = 1, ..., T$, and (v) w_t^b and z_t^b solve the bargaining problem between an employed worker and a firm for $t = 1, ..., T$.

Theorem. A recursive equilibrium exists and is block recursive and unique.

Proof. We construct a *block recursive equilibrium.* Denote a statement "U_t, V_t, F_t, G_t, w_t^u, w_t^a, w_t^b, z_t^b and θ_t are uniquely computed and they depend on ψ only through y for t" as (S_t). We first show that (S_T) holds and then proceed by backward induction.

At age T the value of an unemployed worker with no job offer after the search stage is:

$$U_T^n(h, \psi) = b,$$

and we can write as $U_T^n(h, \psi) = U_T^n(h, y)$.

At the bargaining stage, if an agreement can be reached (the joint surplus is positive), the value of remaining in the current match for a worker without an alternative job offer is given by the bargained wage function:

$$w_T^b(h, z, \psi),$$

while the outside option at this stage is $U_T^n(h, y)$, and the value of the firm (recalling that $F_{T+1} = 0$) is:

$$-w_T^b(h, z, \psi) + \sum_{\{z'\}} \Lambda(z' \mid z)\, f(y, z', h),$$

and the outside value of the firm is zero.

Thus, at age T, the bargaining problem for the continuing match is:

$$\max_{\{w^b\}} \left\{ w^b - b \right\}^{\xi} \left\{ - w^b + \sum_{\{z'\}} \Lambda(z' \mid z)\, f(y, z', h) \right\}^{1-\xi},$$

the joint surplus is:

$$-b + \sum_{\{z'\}} \Lambda(z' \mid z)\, f(y, z', h).$$

Let the cutoff productivity $z_T^b(h, \psi)$ be the lowest z such that the joint surplus is non-negative. Noting that y is the only necessary component in ψ to determine this cutoff, $z_T^b(h, \psi) = z_T^b(h, y)$.

If $z \geq z_T^b(h, y)$, the bargaining problem has a unique solution:

$$w_T^b(h, z, \psi) = (1 - \xi)\, b + \xi \sum_{\{z'\}} \Lambda(z' \mid z)\, f(y, z', h),$$

otherwise the bargaining fails and the employed worker and the firm receive the outside value. We can see that $w_T^b(h, z, \psi) = w_T^b(h, z, y)$.

Therefore, at the bargaining stage the employed worker's value is:

$$V_T^b(h, z, \psi) = \begin{cases} w_T^b(h, z, y) & \text{if } z \geq z_T^b(h, y), \\ b & \text{if } z < z_T^b(h, y), \end{cases}$$

and the firm's value is:

$$F_T^b(h, z, \psi) = \begin{cases} -w_T^b(h, z, y) + \sum_{\{z'\}} \Lambda(z' \mid z)\, f(y, z', h) & \text{if } z \geq z_T^b(h, y), \\ 0 & \text{if } z < z_T^b(h, y). \end{cases}$$

Noting that the right hand sides of the values do not have ψ except y, we can write $V_T^b(h, z, \psi) = V_T^b(h, z, y)$ and $F_T^b(h, z, \psi) = F_T^b(h, z, y)$.

On the other hand, the value of the worker that has found an alternative job offer is simply the wage posted in the market where he has searched:

$$V_T^a(w^a, h, \overline{z}, \psi) = w^a,$$

and this does not depend on ψ directly, so $V_T^a(w^a, h, \overline{z}, \psi) = V_T^a(w^a, h, \overline{z}, y)$. The value of the newly matched firm is:

$$G_T(w^a, h, \overline{z}, \psi) = f(y, \overline{z}, h) - w^a,$$

and hence $G_T(w^a, h, \overline{z}, \psi) = G_T(w^a, h, \overline{z}, y)$.

Then, the free-entry condition for the firm at this stage is (for a wage w),

$$c_v \geq q(\theta_T(w, h, \psi))\, G_T(w, h, \overline{z}, y)$$

and $\theta_T(w, h, \psi) \geq 0$ with complementary slackness. It follows that:

$$\theta_T(w, h, \psi) = \begin{cases} q^{-1}\left(\frac{c_v}{f(y,\overline{z},h)-w}\right) & \text{if } c_v \leq f(y, \overline{z}, h) - w, \\ 0 & \text{if } c_v > f(y, \overline{z}, h) - w, \end{cases}$$

and hence $\theta_T(w, h, \psi) = \theta_T(w, h, y)$ as the right hand side depends on ψ only through y. Equivalently,

$$
\begin{aligned}
w = f(y,\overline{z},h) - \tfrac{c_v}{q(\theta_T(w,h,y))} & \quad \text{if } c_v \leq f(y,\overline{z},h) - w, \\
\theta_T(w,h,y) = 0 & \quad \text{if } c_v > f(y,\overline{z},h) - w.
\end{aligned}
$$

Thus, before the search stage the value of the matched worker is:

$$
\begin{aligned}
& V_T(h,z,\psi) \\
= \; & \max_{\{w^a\}} \Big\{ \lambda_e p(\theta_T(w^a,h,y)) w^a + (1 - \lambda_e p(\theta_T(w^a,h,y))) V_T^b(h,z,y) \Big\}, \\
= \; & \max_{\{w^a\}} \Big\{ \lambda_e(-c_v \theta_T(w^a,h,y) + p(\theta_T(w^a,h,y))(f(y,\overline{z},h) - V_T^b(h,z,y))) + V_T^b(h,z,y) \Big\}, \\
= \; & \max_{\theta \geq 0} \Big\{ \lambda_e(-c_v \theta + p(\theta)(f(y,\overline{z},h) - V_T^b(h,z,y))) + V_T^b(h,z,y) \Big\},
\end{aligned}
$$

so if $f(y,\overline{z},h) \leq V_T^b(h,z,y)$ then the solution is zero, and otherwise the objective function is strictly concave in θ. Thus, this problem has a unique solution $\theta_T^a(h,z,\psi)$. Since the objective function depends on ψ only through y, $\theta_T^a(h,z,\psi) = \theta_T^a(h,z,y)$ and $V_T(h,z,\psi) = V_T(h,z,y)$. Therefore,

$$
\begin{aligned}
w_T^a(h,z,\psi) = f(y,\overline{z},h) - \tfrac{c_v}{q(\theta_T^a(h,z,y))} & \quad \text{if } \theta_T^a(h,z,y) > 0, \\
w_T^a(h,z,\psi) \geq f(y,\overline{z},h) - c_v & \quad \text{if } \theta_T^a(h,z,y) = 0.
\end{aligned}
$$

Noting the market with $\theta = 0$ is empty, without loss of generality:

$$
w_T^a(h,z,\psi) = f(y,\overline{z},h) - \frac{c_v}{q(\theta_T^a(h,z,y))},
$$

and hence $w_T^a(h,z,\psi) = w_T^a(h,z,y)$.

Similarly we have at the beginning of age T value of unemployment:

$$
\begin{aligned}
& U_T(h,\psi) \\
= \; & \max_{\{w^u\}} \Big\{ \lambda_u p(\theta_T(w^u,h,y))w^u + (1-\lambda_u p(\theta_T(w^u,h,y)))U_T^n(h,y) \Big\}, \\
= \; & \max_{\{w^u\}} \Big\{ \lambda_u(-c_v\theta_T(w^u,h,y) + p(\theta_T(w^u,h,y))(f(y,\overline{z},h) - U_T^n(h,y))) + U_T^n(h,y) \Big\}, \\
= \; & \max_{\theta \geq 0} \Big\{ \lambda_u(-c_v\theta + p(\theta)(f(y,\overline{z},h) - U_T^n(h,y))) + U_T^n(h,y) \Big\},
\end{aligned}
$$

so if $f(y,\overline{z},h) \leq U_T^n(h,y)$ then the solution is zero, and otherwise the objective function is strictly concave in θ. Thus, this problem has a unique solution $\theta_T^u(h,\psi)$. Since the objective function depends on ψ only through y, $\theta_T^u(h,\psi) = \theta_T^u(h,y)$ and $U_T(h,\psi) = U_T(h,y)$. Therefore, we uniquely specify as:

$$
w_T^u(h,\psi) = f(y,\overline{z},h) - \frac{c_v}{q(\theta_T^u(h,y))},
$$

and hence $w_T^u(h,\psi) = w_T^u(h,y)$.

The beginning of age T value of the firm previously matched is

$$
F_T(h,z,\psi) = (1-\lambda_e p(\theta_T(w,h,y)))F_T^b(h,z,y),
$$

so $F_T(h,z,\psi) = F_T(h,z,y)$.

Therefore, we can see that (S_T) holds.

We are ready to go back to age $T-1$. The value of a worker that has not found a job at the search stage is:

$$U^n_{T-1}(h,\psi) = b + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)\, U_T(h,y'),$$

so $U^n_{T-1}(h,\psi) = U^n_{T-1}(h,y)$.

At the bargaining stage, if an agreement can be reached through Nash-bargaining, the value for a worker of remaining in the match is:

$$w^b_{T-1}(h,z,\psi) + \beta \sum_{\{s'\}} \Lambda(s' \,|\, s) \Big\{ (1-\delta)\, V_T(h',z',y') + \delta\, U_T(h',y') \Big\},$$

while the outside option at this stage is $U^n_{T-1}(h,y)$. The value of the firm of remaining in the match is:

$$-w^b_{T-1}(h,z,\psi) + \sum_{\{s'\}} \Lambda(s' \,|\, s) \Big\{ f(y,z',h) + \beta\,(1-\delta)\, F_T(h',z',y') \Big\},$$

and the outside value of the firm is fixed at zero.

Thus, at age $T-1$, the bargaining problem for the continuing match is:

$$\begin{aligned} \max\nolimits_{\{w^b\}} \quad & \left[w^b + \beta \sum_{\{s'\}} \Lambda(s' \,|\, s) \Big\{ (1-\delta)\, V_T(h',z',y') + \delta\, U_T(h',y') \Big\} - U^n_{T-1}(h,y) \right]^{\xi} \\ & \times \left[-w^b + \sum_{\{s'\}} \Lambda(s' \,|\, s) \Big\{ f(y,z',h) + \beta\,(1-\delta)\, F_T(h',z',y') \Big\} \right]^{1-\xi} \end{aligned}$$

and the joint surplus is:

$$\sum_{\{s'\}} \Lambda(s' \mid s)\Big\{ f(y,z',h) + \beta\left((1-\delta)\left(V_T(h',z',y') + F_T(h',z',y')\right) + \delta U_T(h',y')\right)\Big\}$$
$$-U^n_{T-1}(h,y).$$

The cutoff productivity $z^b_{T-1}(h,\psi)$ is the lowest z such that the joint surplus is non-negative, and $z^b_{T-1}(h,\psi) = z^b_{T-1}(h,y)$ as above.

If $z \geq z^b_{T-1}(h,y)$, the bargaining problem has a unique solution:

$$w^b_{T-1}(h,z,\psi) = \xi \left\{ \sum_{\{s'\}} \Lambda(s' \mid s)\left(f(y,z',h) + \beta\,(1-\delta)\,F_T(h',z',y')\right) \right\}$$
$$+(1-\xi)\left\{ U^n_{T-1}(h,y) - \beta \sum_{\{s'\}} \Lambda(s' \mid s)\ \left((1-\delta)\,V_T(h',z',y') + \delta\, U_T(h',y')\right) \right\},$$

otherwise the bargaining fails and the employed worker and the firm receive the outside value. We can see that $w^b_{T-1}(h,z,\psi) = w^b_{T-1}(h,z,y)$.

Therefore, at the bargaining stage the employed worker's value is:

$$V^b_{T-1}(h,z,\psi) = w^b_{T-1}(h,z,y) + \beta \sum_{\{s'\}} \Lambda(s' \mid s)\Big\{(1-\delta)V_T(h',z',y') + \delta U_T(h',y')\Big\},$$

if $z \geq z^b_{T-1}(h,y)$ and $V^b_{T-1}(h,z,\psi) = U^n_{T-1}(h,y)$ otherwise. The firm's value is:

$$F^b_{T-1}(h,z,\psi) = -w^b_{T-1}(h,z,y) + \sum_{\{s'\}} \Lambda(s' \mid s)\Big\{f(y,z',h) + \beta(1-\delta)F_T(h',z',y')\Big\},$$

if $z \geq z^b_{T-1}(h,y)$ and $F^b_{T-1}(h,z,\psi) = 0$ otherwise. Thus, we can write $V^b_{T-1}(h,z,\psi) = V^b_{T-1}(h,z,y)$ and $F^b_{T-1}(h,z,\psi) = F^b_{T-1}(h,z,y)$.

On the other hand, the value of the worker that has found an alternative job offer is:

$$V^a_{T-1}(w^a, h, \overline{z}, \psi) = w^a + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)((1-\delta)V_T(h', \overline{z}, y') + \delta U_T(h', y')),$$

so $V^a_{T-1}(w^a, h, \overline{z}, \psi) = V^a_{T-1}(w^a, h, \overline{z}, y)$. The value of the newly matched firm is:

$$G_{T-1}(w^a, h, \overline{z}, \psi) = f(y, \overline{z}, h) - w^a + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)\, F_T(h', \overline{z}, y'),$$

and hence $G_{T-1}(w^a, h, \overline{z}, \psi) = G_{T-1}(w^a, h, \overline{z}, y)$.

Then, the free-entry condition is:

$$c_v \geq q(\theta_{T-1}(w, h, \psi))\, G_{T-1}(w, h, \overline{z}, y)$$

and $\theta_{T-1}(w, h, \psi) \geq 0$ with complementary slackness. It follows that:

$$\theta_{T-1}(w, h, \psi) = q^{-1} \left(\tfrac{c_v}{f(y, \overline{z}, h) - w^a + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)\, F_T(h', \overline{z}, y')} \right)$$

if $c_v \leq f(y, \overline{z}, h) - w + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)\, F_T(h', \overline{z}, y')$, and $\theta_{T-1}(w, h, \psi) = 0$ otherwise, so $\theta_{T-1}(w, h, \psi) = \theta_{T-1}(w, h, y)$ as the right hand side depends on ψ only through y. Equivalently,

$$w = f(y, \overline{z}, h) + \beta \textstyle\sum_{\{y'\}} \Lambda(y' \,|\, y)\, F_T(h', \overline{z}, y') - \tfrac{c_v}{q(\theta_{T-1}(w,h,y))},$$

if $c_v \leq f(y, \overline{z}, h) - w + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)\, F_T(h', \overline{z}, y')$, and $\theta_{T-1}(w, h, \psi) = 0$ otherwise.

Thus, before the search stage the value of the matched worker is:

$$
\begin{aligned}
& V_{T-1}(h,z,\psi) \\
= \; & \max_{\{w^a\}} \Big\{ \lambda_e p(\theta_{T-1}(w^a,h,y))[w^a + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)((1-\delta)V_T(h',\overline{z},y') + \delta U_T(h',y'))] \\
& +(1-\lambda_e p(\theta_{T-1}(w^a,h,y)))V^b_{T-1}(h,z,y) \Big\}, \\
= \; & \max_{\{w^a\}} \Big\{ \lambda_e(-c_v\theta_{T-1}(w^a,h,y) + p(\theta_{T-1}(w^a,h,y))(f(y,\overline{z},h) \\
& +\beta \sum_{\{y'\}} \Lambda(y' \,|\, y)(F_T(h',\overline{z},y') + (1-\delta)V_T(h',\overline{z},y') + \delta U_T(h',y')) - V^b_{T-1}(h,z,y))) \\
& +V^b_{T-1}(h,z,y) \Big\}, \\
= \; & \max_{\theta \geq 0} \Big\{ \lambda_e(-c_v\theta + p(\theta)(f(y,\overline{z},h) + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)(F_T(h',\overline{z},y') \\
& +(1-\delta)V_T(h',\overline{z},y') + \delta U_T(h',y')) - V^b_{T-1}(h,z,y))) + V^b_{T-1}(h,z,y) \Big\},
\end{aligned}
$$

so if

$$
f(y,\overline{z},h) + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)(F_T(h',\overline{z},y') + (1-\delta)V_T(h',\overline{z},y') + \delta U_T(h',y')) \leq V^b_{T-1}(h,z,y)
$$

then the solution is zero, and otherwise the objective function is strictly concave in θ. Thus, this problem has a unique solution $\theta^a_{T-1}(h,z,\psi)$. Then, $\theta^a_{T-1}(h,z,\psi) = \theta^a_{T-1}(h,z,y)$ and $V_{T-1}(h,z,\psi) = V_{T-1}(h,z,y)$ as above. Therefore, we uniquely specify:

$$
w^a_{T-1}(h,z,\psi) = f(y,\overline{z},h) + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y) F_T(h',\overline{z},y') - \frac{c_v}{q(\theta^a_{T-1}(h,z,y))},
$$

and hence $w^a_{T-1}(h,z,\psi) = w^a_{T-1}(h,z,y)$.

Similarly we have at the beginning of age $T-1$ value of unemployment:

$$\begin{aligned}
& U_{T-1}(h,\psi) \\
= \; & \max_{\{w^u\}} \Big\{ \lambda_u p(\theta_{T-1}(w^u,h,y))[w^u + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)((1-\delta)V_T(h',\overline{z},y') + \delta U_T(h',y'))] \\
& + (1-\lambda_u p(\theta_{T-1}(w^u,h,y)))U^n_{T-1}(h,y) \Big\}, \\
= \; & \max_{\{w^u\}} \Big\{ \lambda_u(-c_v \theta_{T-1}(w^u,h,y) + p(\theta_{T-1}(w^u,h,y))(f(y,\overline{z},h) \\
& + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)(F_T(h',\overline{z},y') + (1-\delta)V_T(h',\overline{z},y') + \delta U_T(h',y')) - U^n_{T-1}(h,y))) \\
& + U^n_{T-1}(h,y) \Big\}, \\
= \; & \max_{\theta \geq 0} \Big\{ \lambda_u(-c_v\theta + p(\theta)(f(y,\overline{z},h) + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)(F_T(h',\overline{z},y') \\
& + (1-\delta)V_T(h',\overline{z},y') + \delta U_T(h',y')) - U^n_{T-1}(h,y))) + U^n_{T-1}(h,y) \Big\},
\end{aligned}$$

so if

$$f(y,\overline{z},h) + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)(F_T(h',\overline{z},y') + (1-\delta)V_T(h',\overline{z},y') + \delta U_T(h',y')) \leq U^n_{T-1}(h,y)$$

then the solution is zero, and otherwise the objective function is strictly concave in θ. Thus, this problem has a unique solution $\theta^u_{T-1}(h,\psi)$. Then, $\theta^u_{T-1}(h,\psi) = \theta^u_{T-1}(h,y)$ and $U_{T-1}(h,\psi) = U_{T-1}(h,y)$. Therefore, we uniquely specify:

$$w^u_{T-1}(h,\psi) = f(y,\overline{z},h) + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)\, F_T(h',\overline{z},y') - \frac{c_v}{q(\theta^u_{T-1}(h,y))},$$

and hence $w^u_{T-1}(h,\psi) = w^u_{T-1}(h,y)$.

The beginning of age $T-1$ value of the firm previously matched is:

$$F_{T-1}(h,z,\psi) = (1-\lambda_e p(\theta_{T-1}(w,h,y)))F^b_{T-1}(h,z,y),$$

so $F_{T-1}(h, z, \psi) = F_{T-1}(h, z, y)$.

Therefore, we can see that (S_T) implies (S_{T-1}). Hence, by induction, (S_t) holds for $t = 1, ..., T$, i.e. U_t, V_t, F_t, G_t, w_t^u, w_t^a, w_t^b, z_t^b and θ_t are uniquely computed and they depend on ψ only through y for $t = 1, ..., T$. ■

B.2 Introducing the Tax Wedge

We introduce the tax wedge into the baseline framework, with a focus on the parts of the model that are modified. With a tax wedge τ, if an agreement can be reached through Nash-bargaining at the bargaining stage, the value for a worker of remaining in the match is (at age $T-1$):

$$(1-\tau)\, w_{T-1}^b(h, z, y) + \beta \sum_{\{s'\}} \Lambda(s' \,|\, s) \Big\{ (1-\delta)\, V_T(h', z', y') + \delta\, U_T(h', y') \Big\} \,,$$

while the outside option at this stage is $U_{T-1}^n(h, y)$. The value of the firm of remaining in the match conserves its form. Thus, at age $T-1$, the bargaining problem for the continuing match is:

$$\max_{\{w^b\}} \Big[-w^b + \textstyle\sum_{\{s'\}} \Lambda(s' \,|\, s) \Big\{ f(y, z', h) + \beta\, (1-\delta)\, F_T(h', z', y') \Big\} \Big]^{1-\xi} \times$$
$$\Big[w^b\, (1-\tau) + \beta \textstyle\sum_{\{s'\}} \Lambda(s' \,|\, s) \Big\{ (1-\delta)\, V_T(h', z', y') + \delta\, U_T(h', y') \Big\} - U_{T-1}^n(h, y) \Big]^{\xi}$$

and $\tau \cdot w^b$ is subtracted from the joint surplus in the original problem.

The cutoff productivity $z_{T-1}^b(h, y)$ is the lowest z *such that the surplus of both firm and worker are non-negative.* If $z \geq z_{T-1}^b(h, y)$, the bargaining problem has a unique solution:

$$
\begin{aligned}
& w^b_{T-1}(h,z,y) \\
= \;& \xi\Big\{ \sum_{\{s'\}} \Lambda(s' \,|\, s) \left(f(y,z',h) + \beta\,(1-\delta)\, F_T(h',z',y') \right) \Big\} \\
+ \;& \frac{1-\xi}{1-\tau} \Big\{ U^n_{T-1}(h,y) - \beta \sum_{\{s'\}} \Lambda(s' \,|\, s) \; \left((1-\delta)\, V_T(h',z',y') + \delta\, U_T(h',y') \right) \Big\},
\end{aligned}
$$

otherwise the bargaining fails and the employed worker and the firm receive the outside value.

Therefore, at the bargaining stage the employed worker's value is:

$$
V^b_{T-1}(h,z,y) = w^b_{T-1}(h,z,y)\,(1-\tau) + \beta \sum_{\{s'\}} \Lambda(s' \,|\, s) \Big\{ (1-\delta) V_T(h',z',y') + \delta U_T(h',y') \Big\},
$$

if $z \geq z^b_{T-1}(h,y)$ and $V^b_{T-1}(h,z,y) = U^n_{T-1}(h,y)$ otherwise. The firm's value is:

$$
F^b_{T-1}(h,z,y) = -w^b_{T-1}(h,z,y) + \sum_{\{s'\}} \Lambda(s' \,|\, s) \Big\{ f(y,z',h) + \beta(1-\delta) F_T(h',z',y') \Big\},
$$

if $z \geq z^b_{T-1}(h,y)$ and $F^b_{T-1}(h,z,y) = 0$ otherwise.

On the other hand, the value of the worker that has found an alternative job offer is:

$$
V^a_{T-1}(w^a,h,\overline{z},y) = w^a\,(1-\tau) + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)((1-\delta) V_T(h',\overline{z},y') + \delta U_T(h',y')),
$$

and the value of the newly matched firm is:

$$
G_{T-1}(w^a,h,\overline{z},y) = f(y,\overline{z},h) - w^a + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y)\, F_T(h',\overline{z},y'),
$$

Then, the free-entry condition is unchanged:

$$c_v \geq q(\theta_{T-1}(w,h,y))\, G_{T-1}(w,h,\overline{z},y)$$

and $\theta_{T-1}(w,h,y) \geq 0$ with complementary slackness.

Thus, before the search stage the value of the matched worker is:

$$\begin{aligned}
& V_{T-1}(h,z,y) \\
= \; & \max_{\{w^a\}} \Big\{ \lambda_e p(\theta_{T-1}(\,\cdot\,))[w^a\,(1-\tau) + \beta \sum_{\{y'\}} \Lambda(\,\cdot\,)((1-\delta)V_T(h',\overline{z},y') + \delta U_T(h',y'))] \\
& +(1-\lambda_e p(\theta_{T-1}(\,\cdot\,)))V^b_{T-1}(h,z,y) \Big\}
\end{aligned}$$

Which can alternatively be written as:

$$\begin{aligned}
& V_{T-1}(h,z,y) \\
= \; & \max_{\theta \geq 0} \Big\{ \lambda_e(-c_v\theta\,(1-\tau) + p(\theta)(f(\,\cdot\,)\,(1-\tau) + \beta \sum_{\{y'\}} \Lambda(\,\cdot\,)(F_T(h',\overline{z},y')\,(1-\tau) \\
& +(1-\delta)V_T(h',\overline{z},y') + \delta U_T(h',y')) - V^b_{T-1}(h,z,y))) + V^b_{T-1}(h,z,y) \Big\}
\end{aligned}$$

Using the unique solution $\theta^a_{T-1}(h,z,y)$ for the above problem, we can uniquely specify:

$$w^a_{T-1}(h,z,y) = f(y,\overline{z},h) + \beta \sum_{\{y'\}} \Lambda(y' \,|\, y) F_T(h',\overline{z},y') - \frac{c_v}{q(\theta^a_{T-1}(h,z,y))}$$

Similarly we have at the beginning of age $T-1$ value of unemployment:

$$
\begin{aligned}
& U_{T-1}(h,y) \\
= \; & \max_{\{w^u\}} \Big\{ \lambda_u p(\theta_{T-1}(\,\cdot\,))[w^u\,(1-\tau) + \beta \sum_{\{y'\}} \Lambda(\,\cdot\,)((1-\delta)V_T(h',\overline{z},y') + \delta U_T(h',y'))] \\
& +(1-\lambda_u p(\theta_{T-1}(\,\cdot\,)))U^n_{T-1}(h,y) \Big\}
\end{aligned}
$$

Which can alternatively be expressed as:

$$
\begin{aligned}
& U_{T-1}(h,y) \\
= \; & \max_{\theta \geq 0} \Big\{ \lambda_u(-c_v\theta\,(1-\tau) + p(\theta)(f(\,\cdot\,)\,(1-\tau) + \beta \sum_{\{y'\}} \Lambda(y'\,|\,y)(F_T(h',\overline{z},y')\,(1-\tau) \\
& +(1-\delta)V_T(h',\overline{z},y') + \delta U_T(h',y')) - U^n_{T-1}(h,y))) + U^n_{T-1}(h,y) \Big\},
\end{aligned}
$$

Therefore, using the unique solution $\theta^u_{T-1}(h,y)$ for the above problem, we uniquely specify:

$$
w^u_{T-1}(h,y) = f(y,\overline{z},h) + \beta \sum_{\{y'\}} \Lambda(y'\,|\,y)\,F_T(h',\overline{z},y') - \frac{c_v}{q(\theta^u_{T-1}(h,y))}
$$

The beginning of age $T-1$ value of the firm previously matched is

$$
F_{T-1}(h,z,y) = (1-\lambda_e p(\theta_{T-1}(w,h,y)))F^b_{T-1}(h,z,y).
$$

B.3 Expected Present Discounted Value of Earnings

We compute the expected present discounted value of earnings, for the case of no taxes. At age T the value of an unemployed worker with no job offer after the search stage is $U^n_T(h,y) = b$. We denote the expected present discounted value of earnings as $\hat{U}^n_T(h,y) = 0$. At the bargaining stage the value of an employed worker is $\hat{V}^b_T(h,z,y) = w^b_T(h,z,y)$ if $z \geq z^b_T(h,y)$ and $\hat{V}^b_T(h,z,y) = 0$ otherwise. The value for a worker that finds an alternative job offer is $V^a_T(w^a, h, \overline{z}, y) = \hat{V}^a_T(w^a, h, \overline{z}, y) = w^a$. At the search stage the earnings value of the workers is evaluated at the equilibrium $\theta^a_T(h, z, y)$:

$$\hat{V}_T(h, z, y) = \lambda_e(-c_v\theta + p(\theta)(f(y, \overline{z}, h) - \hat{V}^b_T(h, z, y))) + \hat{V}^b_T(h, z, y)$$

The earnings value of the unemployed worker at the search stage is:

$$\hat{U}_T(h, y) = \lambda_u(-c_v\theta + p(\theta)(f(y, \overline{z}, h) - \hat{U}^n_T(h, y))) + \hat{U}^n_T(h, y)$$

evaluated at the equilibrium $\theta^u_T(h, y)$. Going back one period, the earnings value of an unemployed worker is:

$$\hat{U}^n_{T-1}(h, y) = 0 + \beta \sum_{\{y'\}} \Lambda(y' \mid y)\, \hat{U}_T(h, y')$$

By backward induction we can compute $\{\hat{V}_t, \hat{V}^b_t, \hat{V}^a_t, \hat{U}_t, \hat{U}^n_t\}$ for all t.